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CONTENTS

COVER: A progeny tested German Fleckvieh sire. (Photo: Jan Badenhorst)

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Utilizing animal gene resources

by U.B. Lindström

Lately it has become fashionable to talk about "synthetic breeds," or simply about "synthetics." What do we mean by this expression? *Webster's seventh new collegiate dictionary* defines "synthetic" as something "... produced artificially ... something man-made ... to imitate or replace usual realities." This suggests that making synthetic breeds is comparable to making synthetic fibres from oil. Unfortunately — or perhaps fortunately — this is not so. We cannot yet take the required ingredients from the shelf, mix them in the correct proportions and create a synthetic animal. On the other hand, recent spectacular advances in gene manipulation (Cohen, 1975) suggest that in the future we may well be able to combine genes from widely differing sources, and even from completely unrelated species.

At present, however, it seems preferable to talk about new breeds and reserve the word "synthetic" for situations where it is better suited. A new breed is one which is created by selecting and combining genes from available breeds and strains. This article deals generally with making use of gene resources, and is not restricted to the creation of new distinct breeds. An excellent discussion of the utilization of breed resources is provided by Dickerson (1969, 1974).

Why new breeds?

We can conveniently start by asking: "Is there any need for new breeds?" The successful creation of new breeds in recent times (e.g., Lacombe and Minnesota pigs, Corriedale and Columbia sheep, Santa Gertrudis and Jamaica Hope cattle) could perhaps be taken as an indication of a real need for more work in this field. But how much worse off would we have been if these new breeds had never appeared? It is difficult to say because experimental evidence is very scant. In any event, there seems to have been a demand for some of the new breeds, and we cannot without proof condemn them as useless. In the developing countries the creation of new breeds certainly offers real advantages. For example, the Dorper sheep breed in South Africa, from a cross between Dorset Horn and Blackhead Persian, has proved very useful in Kenya (de Haas, 1972). Thus, new breeds may be able to fit into niches that otherwise would remain empty.

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Advantages

However, it should be stressed that before starting to make a new breed by utilizing several gene pools, one should be fairly confident that it offers some advantages. Among the possible advantages of combining several gene pools are:

(*a*) increase in selection differential;

(*b*) decrease in rate of inbreeding;

(*c*) increase in genetic variation;

(*d*) rapid improvement in some specific trait;

(*e*) heterosis in the first generations;

(*f*) increased efficiency of operations in one population (compared to work in several small ones).

There is no doubt that theoretically some of these advantages might be substantial. In practice, however, it is not as clear. For example, how important is a higher selection differential in cattle, pigs and sheep when so far we have rarely been able to utilize even the selection potential within existing breeds? And is the fear of inbreeding in our major livestock populations (in Scandinavia, for example) anything but a ghost we every now and then take out of the closet to scare each other with? The possible increase in genetic variation might be very useful, but on the other hand there is no evidence that we are running out of genetic diversity, with the possible exception of some poultry populations (Lindström, 1969). The greatest gain in using foreign populations is the possibility of quickly introducing superior genes for a trait where the domestic population is clearly inferior.

If heterosis is of importance in species with a high rate of reproduction, continuous crossbreeding is to be preferred to a combination of gene pools (Dickerson, 1969). In cattle — especially dairy cattle — and sheep, there is much more room for the creation of new breeds. Finally, the smaller the breed is numerically, the stronger is the case for putting its genes into the same basket with those of other populations.

Drawbacks

As is evident from the previous reasoning, there are also drawbacks in combining several gene pools. Among possible disadvantages are:

(*a*) loss of non-allelic (epistatic) gene effects;

(*b*) introduction of undesirable genes into the population;

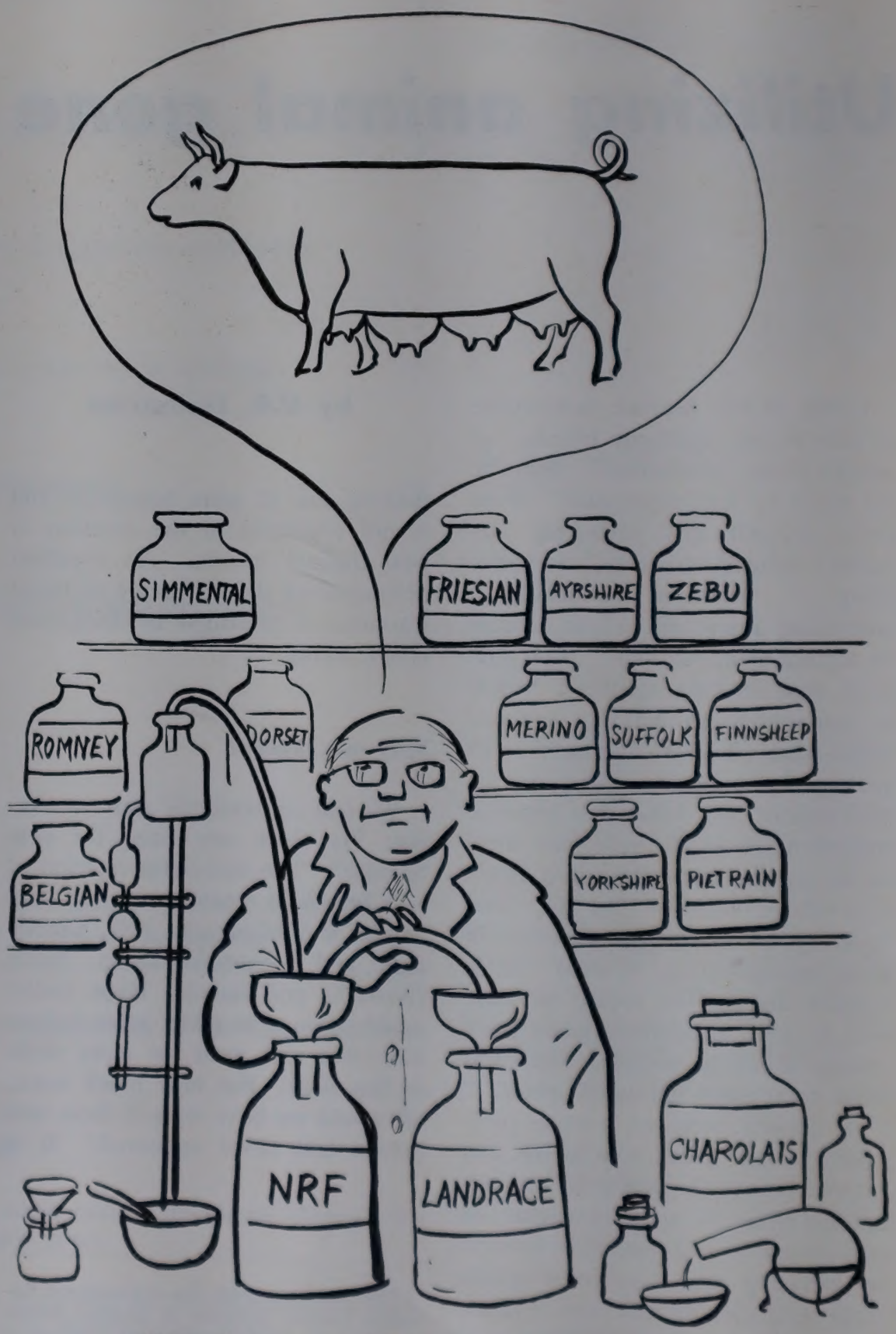
(*c*) disturbance of breeding and selection work with a decreased accuracy of testing in the first generations;

(*d*) loss of crossbreeding possibilities;

(*e*) increased risk of introducing diseases;

(*f*) increased risk of losing genes that may be needed later.

We should not be too worried about the loss of epistatic gene effects (Kempthorne, 1954). Neither is there reason to believe that the risks of losing potentially valuable genes or introducing diseases are of overwhelming importance. The loss in crossbreeding possibilities is, of course, real, but its importance depends



Vision of future possibilities of making synthetic animals

Finnsheep ewes on pasture. The breed's high prolificity has gained attention only recently

greatly on the available assortment of potentially useful breeds (Skjervold, 1970). In cattle this problem would seem to be of less importance than in poultry and pigs, although the indiscriminate spread of the Friesian breed all over the world cannot, in the long run, be regarded as wholly desirable.

Practical difficulties

On the other hand, it is always risky to introduce genes from another population, simply because one does not know exactly what one is getting. It is therefore vital that a carefully planned procedure of selection and evaluation be followed in utilizing foreign populations (see Figure 1). By restricting importation to samples of rigorously tested animals, much (although not all) of the uncertainty can be eliminated. This is what is done in Norway at present in evaluating various dual-purpose cattle populations (Skjervold, 1974).

If the development of a new breed (introduction of foreign genes) is left to individual speculators or breed societies with selfish interests, much harm may be done. In Finland, for example, the introduction of the Friesian breed was made in a manner that resulted in the splitting up of the cow population into unnecessarily large subgroups of pure- and crossbred animals, with repercussions for the progeny testing efficiency within breeds. In 1973-74, Friesian bulls were used on 7 to 10 percent of recorded cows of the Ayrshire and Finncattle breeds. This is, of course, a transitional stage which in the long run may be of little practical importance. Nevertheless, a too rapid dissemination of untested genes involves risks that can easily be avoided by better planning.

What kinds of animals?

Paul Valéry once said: "The only trouble with our time is that the future is not what it used to be." The energy crisis, food shortages and economic recessions in recent times have made all predictions of future requirements more uncertain than ever before. This is also true for animal production, and should seriously be taken into account when discussing what kinds of animals will be needed in the future. In this connexion we can ask the following questions:

1. What species and how many animals of each will we need in various areas?

2. What kinds of breeds (genes) will we need within the next 15, 30 and 60 years?

3. How good is our knowledge of different breeds?

4. Will there be a growing need for breeding animals resistant to difficult conditions and diseases?

5. Will there be barriers to a free exchange of genetic material?

6. Will mutagenesis, sex control and egg transfer be of any importance?

It would be presumptuous even to pretend to know all the answers, but the following views would be relevant.

Ruminants and other animals

With increasing pressure on farmland to supply the world's growing population with food, it seems probable that times will be much tougher for monogastric animals than for ruminants. Therefore, each country would do well to take a closer look at its possibilities and priorities in maintaining various animal species. Obviously, the numbers of the various species might influence the kinds of breeds that are needed. For example, if the pig population in Finland were drastically reduced, what consequences would it have for our cattle breeding policy? Would we have to put more emphasis on beef breeding or would we simply have to make do with a much reduced per caput consumption of meat?

Even if it does not seem probable at present, there might in the future be barriers to the exchange of genetic material. A policy of importing small samples (preferably semen) of breeds that might come in handy some time in the future should be favoured. The importation and storage costs would be negligible compared with the possible benefits from this kind of genetic "insurance policy."

Mutagenesis and sex control

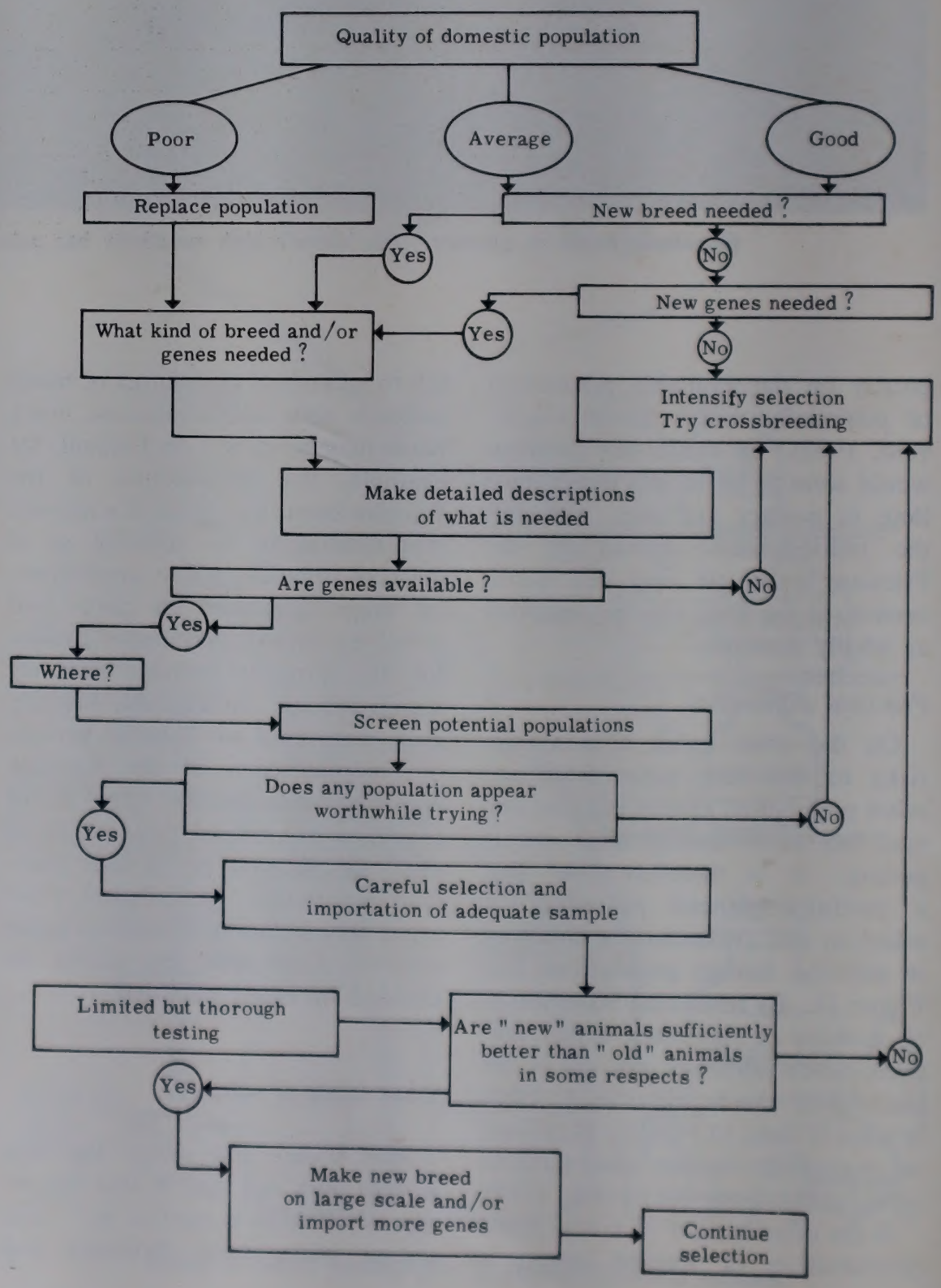
The prospects of achieving results by mutagenesis in large animals are still poor (Bomsel-Helmreich, 1974), and cannot be expected to contribute much in the near future. Is this because it cannot be done, or because we are not trying hard enough? Egg transfers are already a reality, and may, even within 5 to 10 years, begin to play a practical role. Almost every year someone claims to have solved the problem of sex control, but in practice little gain seems to have been achieved (Beatty, 1973).

If predetermination of sex becomes possible, it would certainly influence breeding policies, especially in species with low reproductive rates. The effects would be similar to those of large-scale egg transplantations: when fewer females are needed for replacement, a larger proportion of the population could be utilized for specialized and crossbreeding purposes. Consequently, there would be less need for multipurpose breeds. For example, in cattle there would be improved possibilities of producing the required number of meat animals from specialized beef breed × dairy female crosses (Cunningham, 1975), resulting in reduced demand for dual-purpose sires. Similarly in sheep, improvements in egg transfer and sex determination techniques would promote crossbreeding systems related to those practised in present-day pig production.

What is available?

Although it is hazardous to predict what will be needed within the next 30 or 60 years, the following trends appear likely:

FIGURE 1. Schematic outline of steps in gene resource evaluation



Dorper ewe. The breed can adapt to harsh conditions and is more productive than many indigenous breeds in Africa

1. *Feed efficiency* will be of increasing importance in all species.

2. *Fertility* traits will be given more attention, especially in cattle and sheep.

3. When breeds and individuals are evaluated, considerably more emphasis will be put on *overall economic merit*. Although a discussion of this point is outside the scope of this article, an example is provided in Table 1.

Let us look at these statements from the point of view of utilizing available gene resources. First, it is evident that we really do not know enough about the merits of various breed groups, even those in our neighbouring countries. A good example is the sudden interest in Finnsheep. Records of this breed's prolificity have been available since the 1920s, but it was only in the 1960s (after K. Maijala drew attention to them) that breeders elsewhere became interested. Is it not probable that there are still several very useful breeds in all species that we have not even considered as potential gene resources? At present, it seems that increasing interest is being shown in the French and Italian beef breeds. It is encouraging to see that we are finally beginning to look for genes all over the world, for there is no doubt that we can still derive much benefit from this.

Feed efficiency

Feed efficiency is one trait where screening of foreign populations might be very rewarding. Are there differences in feed conversion between breeds? If there are, how large are they? Our knowledge in this field is far from complete, and solid experimental evidence is hard to come by. For example, are there any differences between the pig breeds of Europe and those of the Far East in this respect? Is it naïve to think that there might be exploitable differences between, for example, the pig breeds of China (which live to a great extent on waste products) and our own breeds? In both dairy and beef cattle there are indications that real differences in feed efficiency exist between breeds (Cundiff, 1974; Dickinson *et al.*, 1969; Henningsson and Brännäng, 1974), but more evidence is badly needed. So far, we have been content to rely on the high genetic correlation between production and efficiency, but will this be sufficient in the future? If we take a new look at this, we may perhaps find that in the long run it pays to record feed consumption in some way. For example, in performance testing young potential AI bulls for growth, feed consumption could be recorded exactly during a limited period (e.g. one to two months) at a reasonable cost. In this way, one could select rather efficiently for the trait itself. Improve-

ments in the technique of measuring feed consumption would be very welcome. Is enough being done in this field?

Individual differences

It has been said that animal breeding is the science of averages. But it is the superior individuals that improve the population. This is especially true when it comes to utilization of gene resources from outside the domestic population. If we want to improve feed efficiency, a thorough screening for exceptional individuals might pay handsome dividends.

The study by Richardson *et al.* (1971), although based on limited numbers, indicates that there may be considerable differences in feed conversion between individuals (see Figure 2). It is interesting to note that the sire that ranked better on the all-forage diet than on the grain-and-forage diet came from New Zealand, where grain feeding is rare.

In general, we can note that as feed resources become scarce and concentrate feeding is practised to a

Table 1 **Information on some cattle breeds in Finland**

Trait	Comments		Breed		
			Ayrshire	Finncattle	Friesian [1]
Live weight of cows	Actual weighings, 1974 [2]	*kg*	497	463	560
Milk yield	Milk recorded herds, 1975	*kg*	4 854	4 150	4 936
Fat	Milk recorded herds, 1975	%	4.41	4.55	4.20
Protein	Only first calvers, recorded herds, average 1972-75	%	3.47	3.53	3.42
Milk yield 4%	Milk recorded herds, 1975	*kg*	5 152	4 495	5 079
Milk yield 4%	Milk recorded herds, 1975	*kg/100 kg live weight*	1 037	971	907
Growth rate of bulls [3]	On performance test station, average 1973-74	*g/day*	1 236	1 129	1 354
60-day non-return rate for AI bulls	1974	%	68.6	73.8	[4] 71.7
Ease of milking cows	In Southwest Finland Agriculture Centre area, 1973-75	*kg/min*	1.83	1.85	?
Stillborn calves	Milk recorded herds, 1974	%			
Heifer dams			3.0	3.8	3.8
Cow dams			2.2	2.1	1.7
Mastitis score [5]	Eastern central Finland area, 1975	*Scale from 0 to 4* [6]			
First calvers			0.159	0.177	0.241
Third calvers			0.448	0.477	0.539
Fifth calvers			0.678	0.713	0.727
Carcass production					
Absolute weight			Somewhat too low	Much too low	Satisfactory
Growth curve			Somewhat too short	Much too short	Satisfactory
Quality of carcass			Average	Poor/average	Average
Feed efficiency					
In milk production			Good?	Satisfactory?	Satisfactory?
In beef production			Average?	Poor?	Satisfactory?
Overall production			Satisfactory?	Average?	Satisfactory?
Fertility					
Bulls			Average?	Good?	Good?
Cows			Average?	Good?	Average?
Overall			Satisfactory?	Good?	Average?
Overall economic merit			?	?	?

[1] Including first and second generation crosses. — [2] Number of cows: Ayrshire 799, Finncattle 323, Friesian 343. — [3] Number of bulls: Ayrshire 430, Finncattle 38, Friesian 50. — [4] Mainly crossings. — [5] Number of cows: Ayrshire 27 149, Finncattle 4 944, Friesian 3 005. — [6] 0 = no mastitis to 4 = culled because of mastitis.

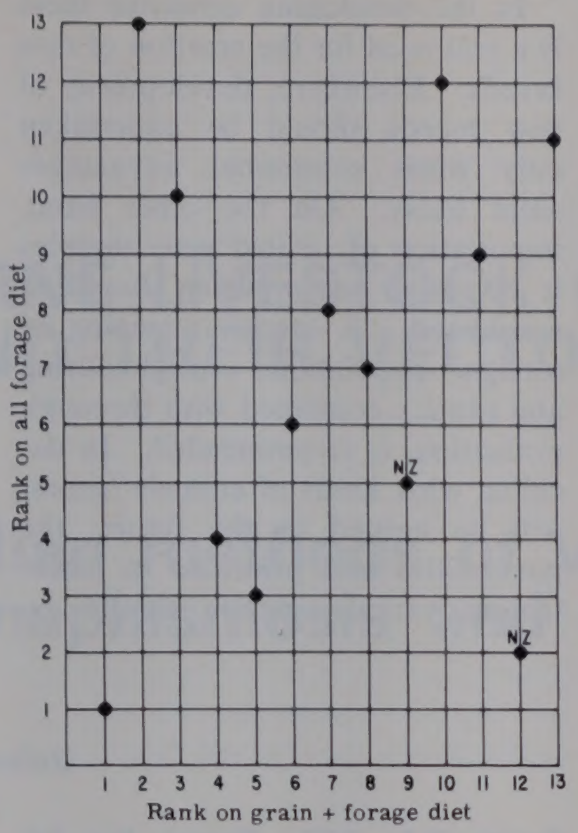
smaller extent, breed and individual differences in feed conversion become more important.

Fertility

Cunningham (1974) has noted that when selection for increased milk production is efficient in the domestic population, it probably does not pay to start importing genes unless the foreign population is at least 20 percent better genetically on an average. With regard to fertility, the situation is quite different, because probably little if any gain is made by selection in most populations (Maijala, 1974). Foreign breeds might therefore help to push the average up immediately if they are superior to one's own animals. Finnsheep have already been mentioned as an example of these possibilities.

In poultry, the previous enthusiasm over the good viability of the Fayoumi breed seems to have faded (FAO, 1973). But is it not possible that if the feeding regime and conditions change in the future — when poultry may well become "scrap animals" again — the breed may once more come into demand? Are there other potentially useful but largely unknown breeds?

FIGURE 2. Performance of 13 Jersey sire dairy progeny groups (228 daughters) on two diets in the United States



SOURCE: Drawn from results of Richardson et al. (1971).

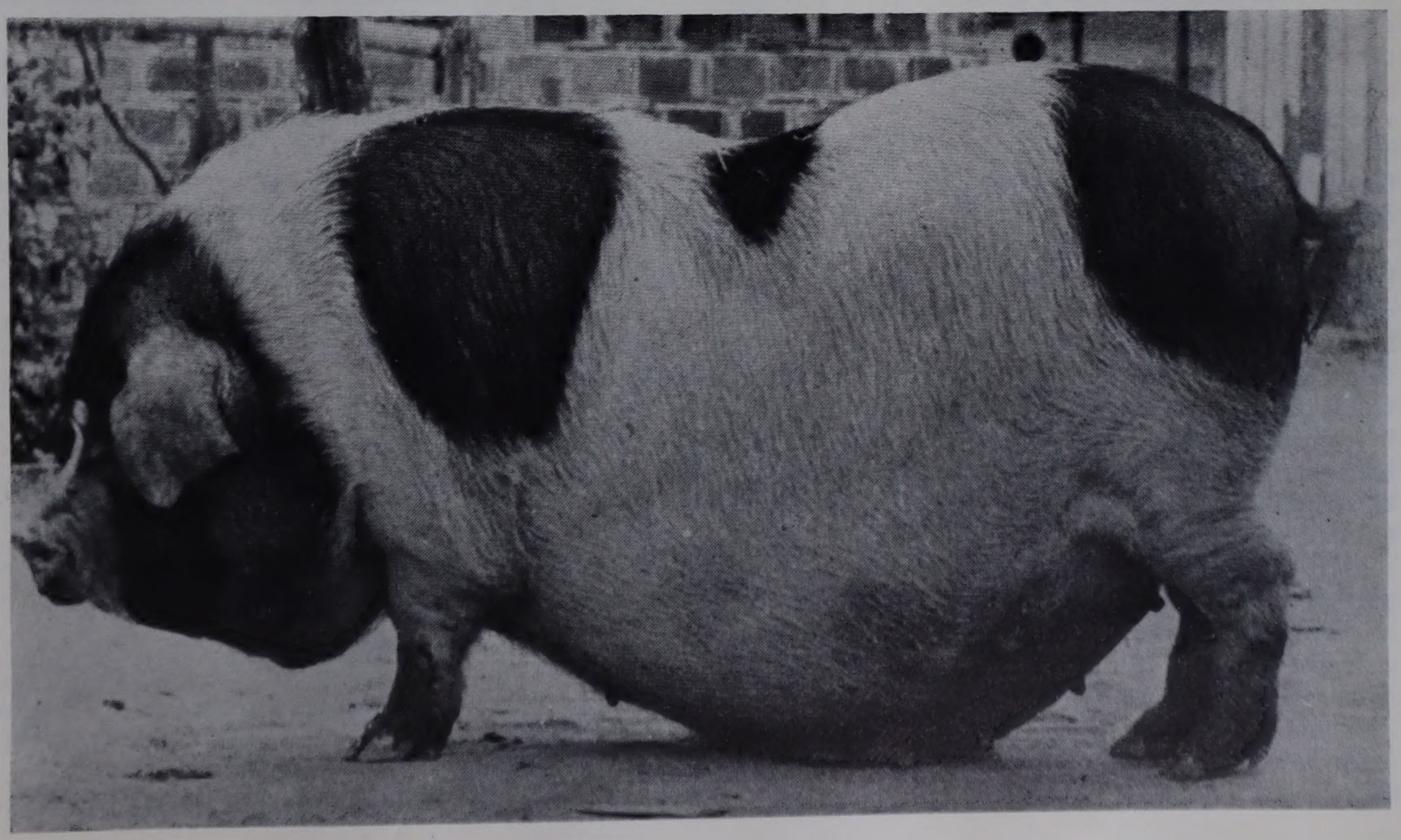
[1] NZ = semen imported from New Zealand.

In pigs, there is not as much to be gained from an increase in fertility as in sheep and cattle, but nevertheless it might be rewarding to study some of the highly prolific breeds of China. This should be done as soon as possible, as the number of breeds is decreasing rapidly (Epstein, 1974).

In cattle, even small improvements in fertility would be of great value. Our knowledge about the genetic quality of different breeds in this respect is rather poor. According to Johansson *et al.* (1974), there seem to be differences among breeds in twinning rate, but it is doubtful if these are large enough for practical utilization. Likewise, it is generally accepted that there are differences among breeds in stillbirth frequency (Van Dieten, 1963). These, as well as the variations in twinning rate, might most efficiently be utilized by selection and use of exceptional (progeny tested) sires.

In Finland, Maijala (1974) has drawn attention to the clearly higher non-return rate (about 5 percent) of

Ninsiang sow from Hunan Province, China. (Photo courtesy of Commonwealth Agricultural Bureaux)



Finncattle compared to Ayrshires. At present very little attention is paid to differences of this kind in most countries, and an objective evaluation of breeds is seldom attempted.

Finally, should we perhaps be a little more worried about genotype × environment interactions? It is possible that in the future our animals will be less well fed and cared for than they are today. In this event, breeds and animals remaining fertile under poor conditions may be in higher demand than at present.

Differences in disease resistance

Incorporating disease-resistant genes from foreign populations (if such genes can be found) theoretically offers enormous benefits. Most geneticists are, however, sceptical about the possibilities. Admittedly, vaccination and other veterinary measures seem to offer a cheaper and more efficient method. On the other hand, we should not forget that there are differences among poultry breeds in resistance to pullorum disease (Hutt, 1974) and that some breeds of cattle are trypanotolerant (Finelle, 1973). Especially with regard to the situation in the developing countries, one should not too hastily dismiss all attempts to breed disease-resistant animals. According to Rendel (1972), in Australia there are clear differences between bull progeny groups with respect to tick resistance.

And what about the mastitis problem? Many veterinarians have unsuccessfully attempted to overcome this by treating cows repeatedly with antibiotics. We know that there are genetic differences among animals in mastitis susceptibility (Hutt, 1974), but we still do not believe they can be utilized in practice. However, we are perhaps unduly pessimistic; according to a study (Lindström, unpublished), it seems that bulls could be progeny tested relatively easily by a simple field test ($h^2 \simeq 10\text{-}15\%$, $N = 23\,200$. See Table 1). Already with first and second calvers there seems to be a fairly large variation between sires.

Summary

In the developing countries there is a real need for the creation of new breeds. Elsewhere, development of new breeds should be undertaken only when substantial advantages seem likely. On the other hand, importation of limited gene samples is always an option which should be considered. A careful screening of foreign populations (neighbouring and exotic), combined with thorough evaluation, is recommended. In deciding what kinds of animals (genes) will be needed in the future, the possibilities and priorities in maintaining various species should be taken into account. Future developments in the techniques of egg transfer and sex control in sheep and cattle are likely to decrease the need for multipurpose animals. It seems probable that in all species feed efficiency and fertility traits will become increasingly important. Utilization of foreign breeds and exceptional individuals with these traits should therefore receive more attention. In the future a higher premium may be placed on animals better able to remain healthy and productive under poorer conditions than those of today. Breeding for disease resistance may one day be successful.

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TICK-BORNE LIVESTOCK DISEASES AND THEIR VECTORS

3. Australian methods of vaccination against anaplasmosis and babesiosis

by L.L. Callow

In Australia, three parasites — *Babesia argentina, B. bigemina* and *Anaplasma marginale* — cause a disease complex commonly known as tick fever. All three organisms are transmitted to cattle by the cattle tick, *Boophilus microplus*. To our knowledge there is no other vector of any consequence in Australia. The three parasites have a worldwide distribution, generally in warm, moist environments that favour *Boophilus*. In some countries anaplasmosis is also widespread in areas where *B. microplus* does not exist. Other species of ticks and biting insects act as vectors.

Vaccination against babesiosis and anaplasmosis is a well-established procedure in Australia. In recent years, more than a million doses of vaccine have been supplied annually. The unique methods by which vaccines are produced are described in this article. Because the epizootiology of the disease complex determines whether or not economic levels of disease will occur, this will be considered briefly. Remarks about *B. argentina* should be considered relevant to *B. bovis* and *B. berbera* because of the probable synonymity.

Transmission

The three parasites causing tick fever are transmitted in different ways by *B. microplus*. Both species of *Babesia* infect engorging ticks, and are transmitted via the egg to the next generation. In this generation *B. argentina* is transmitted to cattle shortly after infestation by larvae, whereas the transmission of *B. bigemina* is delayed for at least nine days until the ticks are nymphs and adults. *A. marginale* is transmitted within the same generation of *B. microplus*. Although it is classified as a one-host tick, *Boophilus* can transfer from one host to another much more readily than was once supposed, and in doing so may also transfer anaplasmosis.

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Calfhood resistance

The young animal tends to be resistant to tick-borne diseases, and this has an important influence on epizootiology. There are two components in the resistance. One is colostral in origin and is conferred if the dam is immune. Whereas this effect is lost within two months, the other component, which is physiological in nature, may be present for much longer. This type of resistance wanes slowly after about nine months. Cattle infected during the resistant period rarely suffer fatal attacks, but nevertheless develop levels of immunity.

Effect of vector density

In common with other arthropod-transmitted diseases, vector density

determines the rate at which cattle become infected with *Babesia* and *Anaplasma*. The question has been very thoroughly examined for *B. argentina* in recent years by CSIRO workers in Australia (Mahoney and Ross, 1972; Mahoney, 1973). Where the tick population is high, most cattle become infected very early in life. In areas less favourable for the propagation of *Boophilus*, although ticks may be constantly present, their numbers are often insufficient to infect a high proportion of cattle in the first year or two of life. The low infectivity of some tick populations results from the surprising fact that the majority of *Boophilus* do not carry parasites. One infected larva in two or three thousand is not uncommon in southern Queensland. The reduction in the transmission rate caused by low vector density is compounded by a tendency of populations to become progressively less infected with parasites as the tick numbers decrease. At times this leads to the complete elimination of *Babesia* and *Anaplasma* from the environment.

Stability and instability

Two situations can thus be broadly defined. The first, termed *enzootic stability*, is associated with frequent transmission of the parasites. In many tropical countries, transmission may be continuous throughout the year. Indigenous cattle suffer minimally from tick-borne disease, but unprotected cattle brought into these areas are immediately infected and often suffer acutely. *Enzootic instability* is an appropriate description of a host-parasite imbalance resulting from infrequent transmission. Disease is seen when the susceptible part of a herd encounters ticks carrying a virulent infection. Enzootic instability similar to that observed in areas of Australia almost certainly exists in large areas of Latin America and possibly in parts of central Asia.

When *Babesia* and *Anaplasma* are

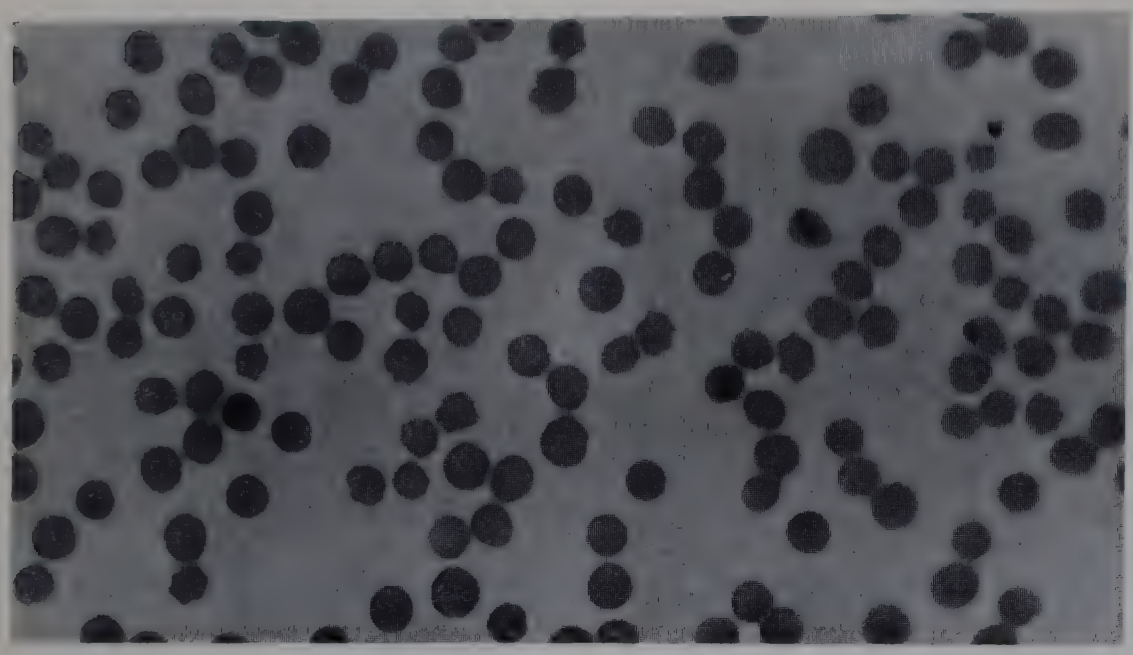
Calf donor of Babesia argentina **vaccine after splenectomy and infection, but before collection of its blood. The vaccine will contain one hundred times more parasites than those in the infective dose**

present in a region, it does not follow that a vaccination programme is essential. If enzootic stability is present and no susceptible cattle are being imported, there should be little evidence of clinical babesiosis and anaplasmosis. If, however, susceptible cattle are being introduced to improve the local cattle industry, or conditions of enzootic instability exist, babesiosis and anaplasmosis are likely to be a problem.

Diagnosis

It is not difficult to determine whether or not vaccination is required to protect imported cattle. Losses of 50 to 100 percent of unprotected cattle have followed their introduction to tropical areas where the transmission rate of tick-borne diseases is high. Decisions on what vaccines should be used, and on whether economic loss due to enzootic instability warrants their use, are not made so easily. In all situations the correct identification of the parasite or parasites causing significant loss is essential. This is often difficult, particularly in developing countries. Morphological similarities between *B. argentina* and *B. bigemina*, inappropriate specimens, substandard equipment and inexperienced diagnosticians can result in mistaken identification. Imported cattle must often overcome barriers other than tick-borne diseases to survive in their new environment. Nutritional and environmental stress, and exposure to other new parasites often confuse the situation. Even in developed regions of Australia, cattle exposed for the first time to excessive numbers of *B. microplus* sometimes die from the effects of the ticks *per se*. These mortalities have been wrongly attributed to failure of vaccination against babesiosis and anaplasmosis. This occurred in Bolivia, when 23 of 80 imported Herefords died from acute anaemia following sudden and heavy infestations with *Boophilus*.

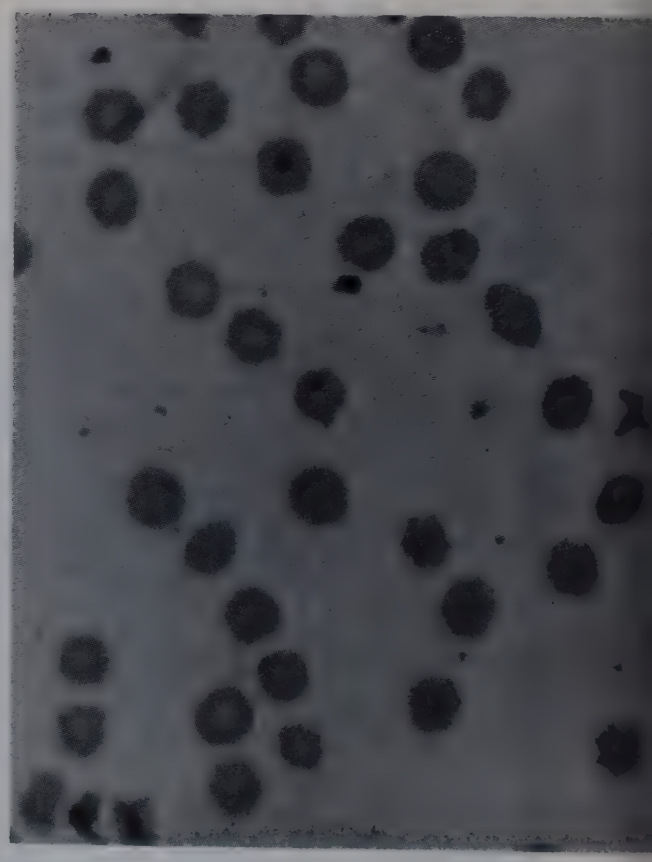
Carotid artery exteriorized and clamped off prior to canulation and exchange transfusion procedure which allows the calf to survive after its heavily infected blood has been collected for vaccine



(Left) Babesia argentina **in a thin blood smear from a vaccine donor**

(Right) Babesia bigemina **in a thin blood smear from an experimental animal**

(Below) Anaplasma centrale **in a thin blood smear from a vaccine donor**



In Australia, as a result of careful study of specimens received at the laboratory over a long period, we know that *B. argentina* is the major pathogen, that incidence of *A. marginale* has increased from 7 to more than 20 percent in a period of 10 years, and that *B. bigemina* can more or less be ignored because of low pathogenicity. These observations have allowed the development of effective control by vaccination in Australia.

Risk due to enzootic instability

Direct evidence for enzootic instability is provided by the observation of disease affecting indigenous cattle, mainly in the age group of one to three years. Incidence is usually seasonal, the peak coinciding with maximum tick activity. The extent of the losses should indicate whether or not vaccination is warranted. In remote areas where disease incidence cannot be effectively observed, evidence for enzootic instability can be obtained by serological surveys. In an FAO study performed in a mountainous region of Bolivia, antibodies against *B. argentina* were found in 38 percent of mature cattle. The 62 percent that had not been exposed were considered to be at risk. The symptoms that local farmers described in their cattle strongly suggested infection with tick-borne disease. Vaccination would be advantageous in such a situation.

Resistant cattle

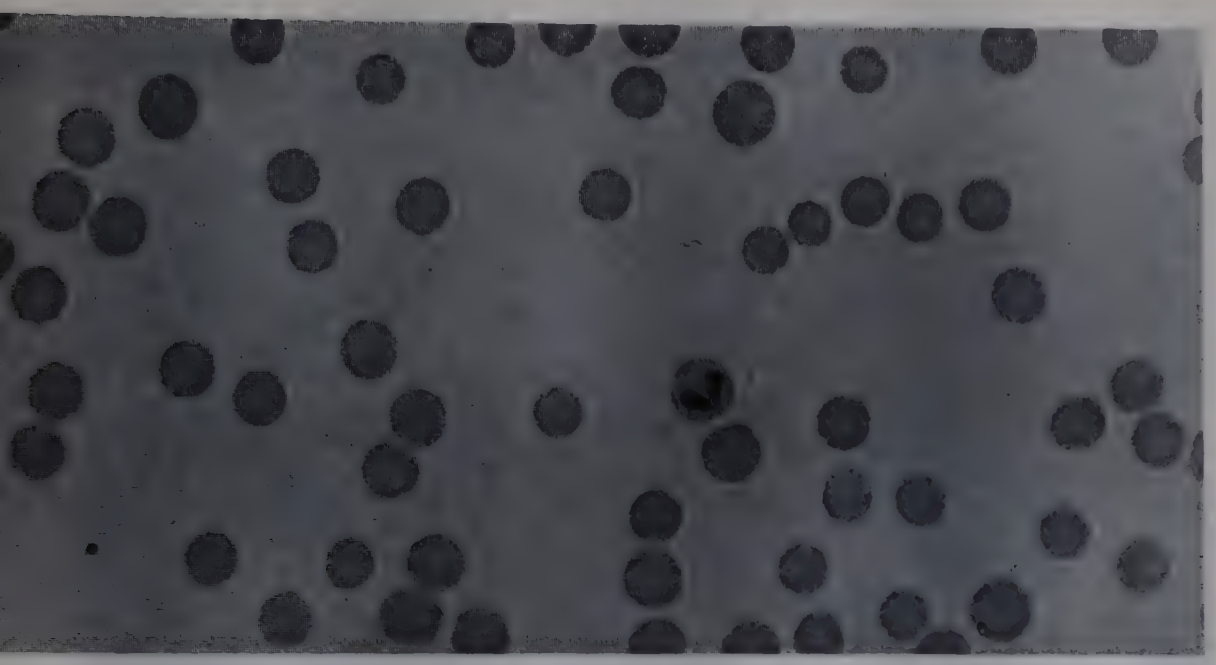
Another factor in deciding whether or not vaccination is warranted is the composition of the herds in a region. Probably as a result of thousands of years of close association, some breeds of zebu cattle are not seriously affected by the parasites. Although it would be advisable to vaccinate previously unexposed zebu-type cattle being introduced into a heavily infected environment, it may not be necessary to protect them in conditions of enzootic instability where the challenge is not as severe.

Tick eradication programmes

Another indication for vaccination is in tick eradication programmes. Experience in Australia has been that *Boophilus* can be suppressed readily, but is a most difficult pest to eradicate completely. Repopulation of a region with ticks after only two or three years of freedom can cause serious losses when babesiosis and anaplasmosis return. No tick eradication programme should be attempted without first ensuring that adequate supplies of vaccine will be available if needed.

Vaccination

For over 75 years, vaccination procedures of varying effectiveness have been used. Until the 1960s the carrier donor system was used in Australia to provide vaccine. Carriers



of *Babesia* held at the laboratory were used to vaccinate against the species occurring in the field. For anaplasmosis, however, the immunizing agent used against *A. marginale* was frequently *A. centrale*. When laboratory services were not available, herd animals were selected as donors on the assumption that they carried the parasites against which protection was required. Similar systems have been used in Algeria, Israel, South Africa, Sri Lanka and Sweden, and also in some South American countries.

Developments in Australia

Increasing dissatisfaction with the carrier donor method in Australia during the 1950s resulted in investigations that showed that carrier donors of *Babesia* provided infective vaccine in only 60 to 70 percent of cases (Callow and Tammemagi, 1967). This finding was followed by the development of highly infective but relatively attenuated vaccines against babesiosis and anaplasmosis (Callow and Mellors, 1966; Callow, 1971).

The salient features of the Australian vaccines are as follows:

- Each dose of vaccine contains 10 million viable parasites, about one hundred times the infective dose. Large numbers of parasites are produced in splenectomized calves.
- Repeated passaging in splenectomized calves has two desirable effects: *B. argentina* and possibly *A. centrale* undergo a decrease in virulence; there is a loss of infectivity of the parasite for the tick vector.
- *B. bigemina* is not routinely included in vaccine because epizootiological studies showed it to be a minor cause of disease. However, infective vaccine of reduced virulence can be prepared by utilizing relapse parasitaemias provoked by splenectomizing carriers of this parasite.
- Parasitized erythrocytes are suspended in a cell-free, plasma-based diluent. The erythrocyte component of the vaccine averages 0.1 ml. The reduced volume of whole blood in vaccine minimizes the risk of breeding females developing antibodies against incompatible blood. These do not harm the mother, but may cause a haemolytic syndrome in newborn calves after they have ingested colostrum. The diluent is especially designed to preserve the infectivity of the vaccine.
- Vaccine is dispatched in ice inside insulated containers to prevent deterioration in transit.
- The vaccine strain of *B. argentina* is changed periodically. Babesial immunity is reinforced by a second vaccination, and it is greatly improved when this is made with a strain different from that used at the initial infection.

Use of vaccine

In recent years approximately 1.3 million doses of vaccine have been supplied to vaccinate 8 000 herds of cattle. Most of the vaccine required in the past was monovalent *B. argentina*, but recently the demand for *A. centrale* has increased sharply so that about 25 percent of the vaccine currently being supplied contains this organism. Most of the vaccine is used in cattle under 12 months of age living in conditions of enzootic instability. Although one vaccination is probably sufficient for these conditions, a second is often given about six months after the first. The incidence of severe reactions is so small that close supervision of cattle following vaccination is seldom practised. About 12 reports of breakdown of immunity following natural

challenge of vaccinated cattle are received each year. Related to the estimated number of cattle vaccinated, this represents an incidence of less than 0.25 percent. A recent study showed that unvaccinated cattle were 16 times more likely to suffer clinical attacks than vaccinated animals. Haemolytic disease of calves was a problem some years ago (Langford *et al.*, 1971) when the vaccine was wholly comprised of blood, and farmers considered that maintenance of immunity required frequent vaccinations. The introduction of the cell-free diluent and less frequent vaccinations have reduced the incidence of this condition to negligible proportions.

Four-litre plastic bags of vaccine components held in cold room at 2-4°C

Applicability of Australian findings for other regions

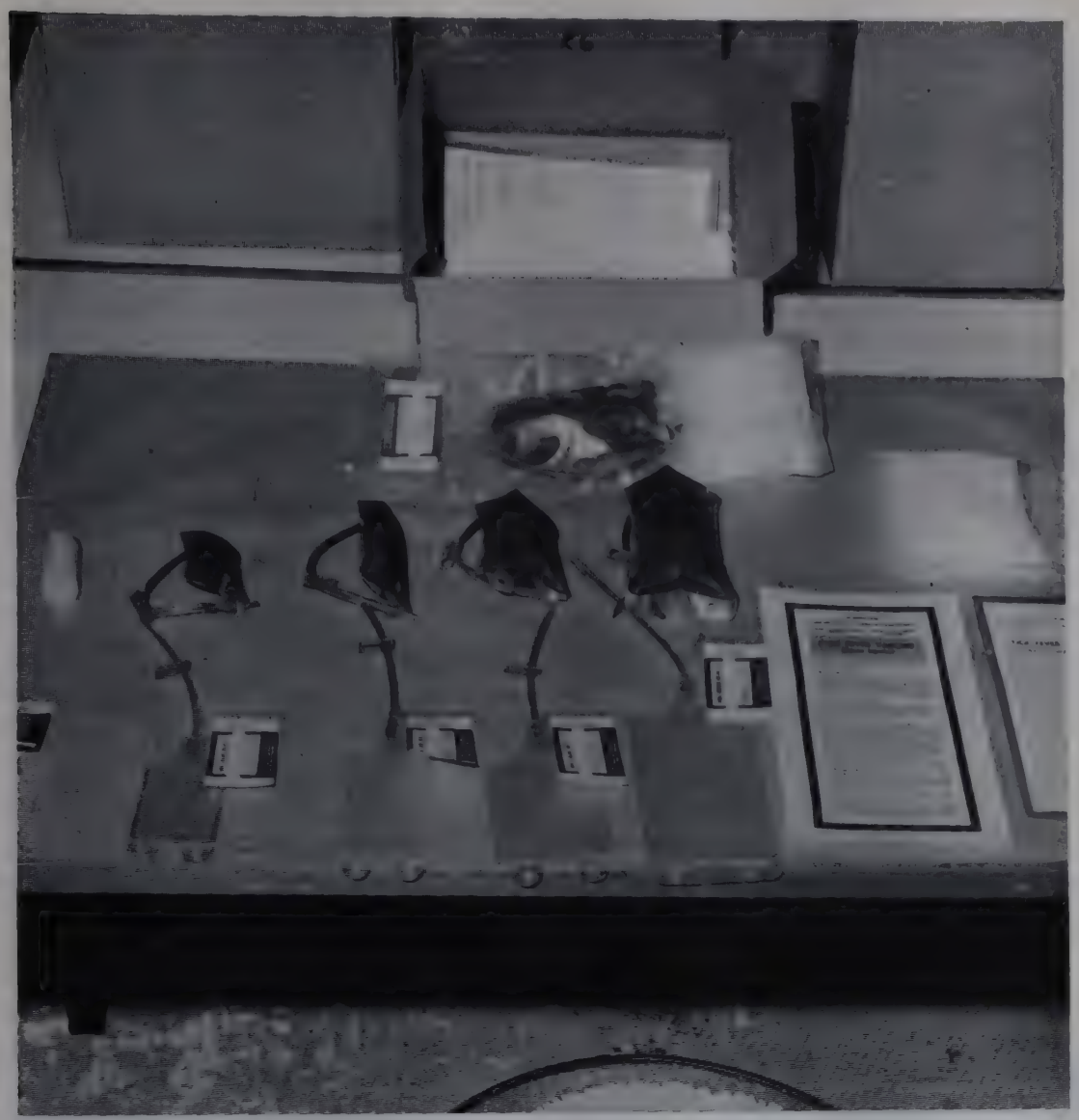
The progress made in Australia in dealing with babesiosis and anaplasmosis has resulted from the resources of a developed country being applied to the solution of a problem of economic significance. In evaluating the usefulness of this approach for solving similar problems in developing countries, a number of questions must be considered.

The first questions concern whether or not the procedures are within the capability and resources of a developing country. Elaborate equipment is not necessary, but it is essential that some special training be provided for persons responsible for vaccine production. Great depth of knowledge is not essential because the principles are not difficult. However, personnel should be responsible and alert because there is a risk of spreading disease in a live vaccine based on fresh bovine blood.

A significant problem for some developing countries is to obtain animals known to be free of tick-borne infections and to protect them from natural infections during vaccine production. Special tick-free facilities at the laboratory — and possibly breeding programmes within them — may have to be established to satisfy this requirement.

In Australia vaccine is produced continuously to meet a large demand. Because it is perishable, new batches must be prepared every week. This could be a difficult task in a developing country. It could also be extravagant in many instances because the annual demand might not exceed a few thousand doses required for protecting imported cattle. A solution is the preparation of batches followed by viable preservation in the frozen state. Effective procedures are now available (Dalgliesh and Mellors, 1974), and have been used for several years in the FAO project in Bolivia, where Australian-type vaccine is held in liquid nitrogen until required.

Other questions concern the immunological similarities of the *Babesia* transmitted by *B. microplus*. Will cattle immunized in one area survive challenge in another, and could a single vaccine be used in more than one region? Cattle immunized in Australia and exported to Southeast Asia do not suffer from tick-borne diseases. Some years ago, cattle immunized in Australia were exported to Trinidad without difficulty. Recently, McCosker (1975) found that Australian strains of *B. argentina* could be used as vaccine in Bolivia. This was followed by a laboratory study showing that Australian and Bolivian strains of *B. argentina* were serologically identical. Other recent studies (Goldman and Rosenberg, 1974) have shown immunological similarities in *B. bovis*,



Display of vaccine bags, method of packing in ice and insulating material

B. argentina and *B. berbera*. A vaccine prepared with any of these parasites could be applicable wherever *Boophilus* transmits babesiosis.

"Boosting" with a heterologous strain of *B. argentina* raises the level of immunity, but is not always considered necessary in Australia. In more tropical environments, where the challenge is intense, two vaccinations with different strains would be an advantage. Inclusion of *B. bigemina* in vaccine has not proved necessary in Australia and Bolivia because of the low pathogenicity of field strains, but in other environments protection against this species may be required. Both *B. bovis* and *B. bigemina* are pathogenic in South Africa. In Australia, *A. centrale* has protected successfully against *A. marginale*. Again because of the probability of stronger challenges, *A. centrale* may not be completely satisfactory in some tropical regions. Its combination with relatively avirulent laboratory strains of *A. marginale* alone, specially processed for vaccine, might be necessary.

Conclusions

Immunity against babesiosis and anaplasmosis is obtained in Australia with reliably infective vaccines produced by manipulating strains of *Babesia* and *A. centrale* in the laboratory. These methods could have worldwide application. They could be adopted totally in countries where the epizootiology of the diseases is similar to that in Australia. Several alternatives exist for other regions where it would be difficult or unnecessary to maintain continuous production. These include limited production and the establishment of frozen stores of vaccine, or provision of vaccine by a foreign centre engaged in regular production. As an alternative to isolating and processing indigenous strains of parasites for vaccine, these might be obtained from Australia. Strains have been found to be immunogenic in regions far removed from this country. Vaccine strains currently used in Australia are also of reduced virulence and are incapable of being spread by ticks.

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New facets of animal breeding research in the United States

by R.L. Willham

Animal breeding, as an applied field of population genetics, has a well-developed mathematical foundation that was laid early in its development. Facets of major emphasis in current animal breeding include the utilization of new estimation procedures for random effects, the incorporation of economics in the development of breeding programmes designed for the livestock industry, the verification of theory and testing of breeding schemes using laboratory organisms, the evaluation of new germ plasm available in livestock populations, and the application of breeding principles to the livestock industry. There are real opportunities in animal breeding to serve the current livestock industry. This article presents one view of animal breeding and of the facets currently being researched as seen by a professor of animal breeding at a midwestern land-grant university. The relevant terminology is defined, an historical perspective is provided and the current facets of animal breeding are presented.

The science of animal breeding is concerned with the application of the principles of population genetics to the improvement of domestic animals. Population genetics deals with the forces that influence the genetic composition of biological populations and owes its existence to developments in evolution and population biology and to the global need for improvements in domestic crops and livestock. Livestock breeders, using selection, adapted their stock to meet this need long before animal breeding became a science. With the rediscovery of Mendel in 1900, Wentworth and other animal husbandmen began to explore the art of the breeder in the light of Mendelian genetics. Concurrently, the basic theory of population genetics was formulated by Fisher and Wright. Never before in the history of biology had theory, based on the algebra of ½, so outstripped experimental evidence in any field. This has tended to make population genetics (and, as a result, animal breeding) unique among the sciences. During this formative period, hybrid maize had its first impact on the scientific community and on agricultural production.

Research, teaching and extension

Lush developed a graduate programme starting in the 1930s that produced students trained to apply the principles of population genetics to the improvement of domestic livestock. The 1940s saw dairy artificial insemination, and Dairy Herd Improvement Association (U.S. Department of Agriculture) records, with their symbiotic effect on sire evaluation, begin the revolution in dairy cattle breeding. The poultry industry quickly developed a few giant poultry breeding companies.

After the Second World War, several regional projects, patterned after the successful regional swine-breeding laboratory, were started with adequate funding from state experiment stations and the U.S. Department of Agriculture to initiate some large-scale animal breeding research projects. Today the fruits of these long-term investigations are seen in the dairy, poultry, swine, sheep and beef industries. The extent of breeding technology utilized by the various industries is related to their reproductive potential or to a reproductive innovation such as artificial insemination.

Animal breeding research has been conducted mainly in the structure of land-grant universities under the leadership of professors with responsibilities in research, teaching and, to some extent, extension. Research provided the primary base of experience which influenced teaching and extension. Large animal research in the field of breeding was developed through long-term projects in experiment stations. Typically this research approached genetic problems peculiar to a species, such as the amount and kind of genetic variation available, the heritability and repeatability of traits, and the response to inbreeding and crossbreeding. Considerable theoretical studies resulted from a need to explain research findings, as evidenced by the development of concepts relating to maternal effects (Dickerson, 1974).

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Animal breeding research tended to develop breeding technology that can be applied by breeders in the various livestock industries. This contrasted with plant breeding research, where the basic germ plasm was developed by the plant breeders themselves. The controversy over these two philosophies of research has been exciting, but the development of breeding principles has prevailed.

Today, research in animal breeding has problems both in large and laboratory animals. Funds for this research are being reduced by inflation and by an emphasis on short-term projects with the highest probable net return to the livestock industry. Also, in the land-grant system excellence in teaching is emphasized, sometimes at the expense of research. Nevertheless, important biological and theoretical questions remain unanswered in animal breeding. Opportunity does exist for research even though the scope of investigations and the basic nature of the projects may be changing. The development of research capabilities by the livestock industry itself and by the U.S. Department of Agriculture in large-scale projects, when coupled with university research, can add substantially to knowledge in the field of animal breeding.

Inasmuch as animal breeding is an applied field, it becomes difficult to decide when work is primarily population genetics and when it is animal breeding. The line is somewhat like the difference between applied and fundamental or basic research. To pick up contributions from the field of molecular, classical and physiological genetics and from evolution and population biology is even more difficult. The general facets of current work in animal breeding may be classified into theoretical animal breeding, animal research and application. Each of these facets may in turn be further subdivided.

Theoretical animal breeding

This is defined as the development of a concept, usually with a mathematical basis, that contributes new knowledge to the field of breeding and is not species-bound. This facet is subdivided into statistical, genetic and economic areas of theoretical development.

Statistical: New concepts and procedures in statistics have been contributed by animal breeders over time. These are in part the result of dealing with large volumes of

Crossbred market swine are the rule in commercial production

nonorthogonal data. The development of the selection index by Hazel and Lush (1942) opened new vistas of theoretical development.

Recently, Henderson (1972, 1975) has consolidated work that extends statistical theory to the estimation of random variables and the estimation of maximum likelihood estimates of fixed effects. It utilizes selection index concepts along with those of least squares. This new theory is currently being used in dairy and beef sire evaluation. This area of statistical estimation is being actively pursued, as evidenced by the work of Freeman (1973) and Powell *et al.* (1975). The development by Harvey (1960) of least-squares analysis of data with unequal subclass numbers and his subsequent writing of analysis programmes have been utilized by breeders and are responsible for considerable statistical sophistication in the breeding literature.

Genetic: The bulk of the theoretical papers in this area are really oriented toward population genetics rather than strictly toward breeding. The work of Fitzhugh and Taylor (1971) in developing theory to interpret growth by using concepts of degree of maturity and mature size have made a contribution to the study of new germ plasm having a large range of mature sizes. Work on growth curve estimation, as illustrated by Brown *et al.* (1974), has added a new dimension to the study of one of the more important economic traits of livestock production. The concept of complementarity defined by Fitzhugh *et al.* (1975) completes the development of a sound theory for crossbreeding. Complementarity involves introducing into a crossbreeding system breeds that complement each other in the production of a sound maternal strain and a market animal.

Genetic simulation using computers, as exemplified by Fraser and Burnell (1970), is not at present an active area of investigation in breeding, but the use of computer simulation with linear models and the breeding value concept have been adopted extensively to teach and demonstrate genetic principles. Some research in developing breeding plans has been undertaken recently. Theoretical work on selection response continues, as illustrated by the work of Hill (1974) and Olliver (1974).

Economic: The "big boom" facet of animal breeding today is in the area of economic integration. Monetary values are being involved in what used to be an area where genetic change per year alone was the criterion of choice among programmes. Hill (1971) looked at discounted cash-flow concepts in his appraisal of investments in national breeding programmes. This concept has been applied to many situations recently. Dickerson *et al.* (1974) have examined selection criteria for efficient production by using economic inputs. Pearson and Freeman (1973) looked at profitability in dairy operations rather than at those making the most rapid genetic change.

Probably the most detailed work of combining linear programming from economics to the development of livestock systems analysis has come from Texas. Long *et al.* (1975), Fitzhugh *et al.* (1975) and Cartwright *et al.* (1975) have reported work in this area. Morris *et al.* (1975) at Guelph are also doing work with systems analysis.

This integration of economics in livestock production theory has done several things in the field of breeding. First, and probably most important, it has clearly isolated areas of biology, including some in breeding, in which little if anything is really known. Some of these areas are now receiving attention in well-designed projects. Second, it has given real economic importance to segments of production that before have received little if any attention from the breeder. The best example is the cost of

A freeze branding demonstration

animal size in the breeding herd. This area of animal breeding (or more correctly, the contribution of breeding to the study of livestock systems) will expand in emphasis in the future. There are many concepts in economics that take large numbers of variables into account in the optimization process that can be utilized to build a new facet in animal breeding theory.

Animal research in breeding

Research in this area is being conducted by universities, government organizations and, to a small extent, by the several livestock industries themselves. It is convenient to consider this research under laboratory animal research and large animal research.

Laboratory animal research: Numerous selection studies continue to be reported, such as those of Orozco and Bell (1974), Bell and Burris (1973), Falconer (1973), Frahm and Brown (1975) and Bateman (1974). Also, Bohren (1975) has dealt with the design of selection studies for specific objectives. In general, these studies continue to confirm existing theory. Some problems still need clarification, particularly those concerning correlated response.

Maternal effects have been extensively studied by using laboratory organisms, especially mice. This work is exemplified by that of Hanrahan and Eisen (1974) and by several theoretical studies by Eisen on maternal effects. Bradford *et al.* (1974) have examined egg transfer, and Sanders *et al.* (1975) have looked at Falconer's maternal effect model in cattle. Meyer and Bradford (1974) have investigated the reproductive complex, as have earlier studies of Falconer with mice. Because the reproductive complex becomes increasingly more important economically in species with a low reproductive potential, pilot work in this area of reproduction genetics may be fruitful and of major importance to the livestock industry.

Large animal research: In the United States several regional large animal research projects were initiated after the Second World War, with most midwestern universities contributing. The fruits of these projects have been utilized by the respective industries. Many universities, and especially the U.S. Department of Agriculture, have large animal breeding projects in progress.

These studies have involved determining the amount and kind of genetic variation for traits of economic importance and evaluating the effects of inbreeding and crossbreeding. Koch *et al.* (1974a, 1974b) reported on a beef cattle selection study that is still in progress. Bereskin *et al.* (1974) presented some of the results from the classic high-low selection study for backfat in swine. These studies and others in progress tend to confirm earlier theoretical work.

As noted above, the most economically important class of traits is the reproductive complex. The role of heredity in reproduction has been considered by Zimmerman and Cunningham (1975), Laster (1974), Pumfrey *et al.* (1975) and Rankin and Okidi (1975). Work on the introduction of more prolific breeds of sheep into the United States has been reported (e.g., Price and Ercanbrack, 1975).

Among the more important areas of current research is new germ plasm evaluation in sheep and cattle. Since 1967, when importation of this germ plasm into the United States became possible from Canada, the beef industry in particular has felt the need for research that compares and characterizes the new breeds under United States management situations. The new U.S. Department of Agriculture research station at Clay Centre, Nebraska (the U.S. Meat Animal Research Centre, known as U.S. MARC), has undertaken a massive

The backfat probe developed by Hazel in 1952

project to do this evaluation. Its latest report (1975) compares a number of the newly introduced European draught and dual-purpose breeds with the traditional Hereford and Angus breeds under United States management conditions. The speed with which these reports are utilized by the beef industry in real decision-making is remarkable.

The importation of beef cattle that differ in rate of maturity and eventual mature size has prompted the animal breeder to investigate genetic comparisons under several alternative environments, and not just one as had usually been done. The germ plasm evaluation project involves three slaughter ages for each of the breeds compared. Work of Anderson (1975) and other workers involved in evaluating dairy breeds in beef production suggests that unless managed carefully (by feeding more energy at appropriate times), the dairy breeds fail to rebreed adequately compared with the traditional beef breeds. Again, this involves matching the breed and the environment for compatibility.

As always, studies on inheritance and on ways to eliminate deleterious single genes from populations of livestock are under way. The work of Christian (1972) with pale, soft, exudative pork muscle and the porcine stress syndrome in swine, and of Kieffer *et al.* (1972) with the double muscle syndrome in cattle, are examples.

Some genetic work is still being done with blood antigens and other aspects of physiological genetics, as indicated by the studies of Bryan *et al.* (1975) on the cattle histocompatibility system.

Because of the genetic capabilities of large poultry breeding firms, university work in poultry breeding has developed more basic projects (e.g., Nordskog *et al.*, 1974).

Application of animal breeding

A new applied field must first generate enough knowledge from research and develop enough trained people before it can have an impact on the industries in which it is to be applied. Such has been the case with animal breeding.

Little real application of population genetics theory was made to domestic livestock until after the Second World War. Since then, several livestock industries have been revolutionized and the larger species with lower reproductive potential are now yielding to the impact of breeding technology. Large breeding organizations are well-established in poultry; although there are not many of them, they control the genetics of both broiler and egg production. The swine industry has not gone this far, but at least two organizations are involved in swine breeding. Swine testing stations are now an integral part of the industry. Dairy cattle breeding, because of the early use of artificial insemination, has developed a complex of strong bull studs, nearly all of which have young sire sampling programmes and, as such, are taking a real lead in dairy breeding.

The use of Dairy Herd Improvement Association records has become quite sophisticated, with cow as well as sire evaluations being made on several sets of relative groups combined into a selection index. Beef cattle breeding has just begun to have an impact on the very traditional beef industry. There are now 11 breed-wide national sire evaluation programmes. Data from these are being analysed with the procedures of estimation developed by Henderson (1972). At least three breeds provide estimates of breeding value on individual animals in their performance programmes. Performance pedigrees are now in vogue.

But possibly the most unique aspect of beef breeding is the Beef Improvement Federation which is a federation of organizations conducting performance programmes in the beef industry. Through this federation, guidelines for establishing performance and sire evaluation programmes and for measuring and recording traits are established. Most organizations conform to these guidelines, which have been developed by animal breeders engaged in research and/or extension work. The Beef Improvement Federation provides the perfect vehicle for animal breeding to be applied in an industry. The United States breeds have responded to the performance challenge rather better than Lerner and Donald (1966) earlier supposed. While this application of breeding technology has been going on in the United States, more exciting large-scale breeding programmes have been launched in Europe.

The classic work of Skjervold (1966), dealing with selection schemes and artificial insemination, has now been applied by Skjervold and his associates on a national scale in dairy cattle breeding in Norway. With the advent of the Meat and Livestock Commission in the United Kingdom, national as well as breed schemes have been developed, and some are being applied. Three scientific study groups have made comprehensive reports on the swine, beef and sheep industries. These groups contained both theoretical and applied animal breeders who reported on alternative breeding schemes and made recommendations on those most likely to bring a profit to the industry. Other European countries also have national breeding schemes for cattle, swine and sheep. In time, these programmes can yield valuable information to the store of breeding knowledge.

Summary

Animal breeding, as an applied field of population genetics, is endowed with a mathematically sound theory developed early in its history. Both theoretical and applied problems in breeding remain to be solved, although they are not as obvious as was once the case. Real opportunities exist for the animal breeder who is willing to make use of new knowledge generated in other areas of genetics and of the store of theory developed in economics. Even with reduced research funds it will be possible to serve the livestock industry creatively, especially when industry itself can develop a suitable data base.

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ANIMAL HEALTH AND MANAGEMENT PROBLEMS IN LARGE-SCALE CATTLE UNITS

by F. Kovács

There is a growing trend in many parts of the world toward specialized cattle production based on large-scale enterprises which aim at higher outputs of meat and milk. However, only healthy herds in which the productivity of the animals is consistent with the genetically determined performance standards of the breed or type can be expected to achieve at lower cost the intended improvements in production. The main animal health requirements to be met in these large systems are the following:

(*a*) preventing the introduction and spread of pathogenic agents from sources outside the unit;

(*b*) providing environments physiologically optimal for livestock, within economic limits;

(*c*) giving attention to the habits and behavioural patterns of the species or breed when creating the elements of the environment.

Control of infectious diseases

In recent years, increased concentrations of livestock and trade in animals, tourism, and various other circumstances have stimulated the integration of measures for infectious disease control into the management system. The basic principle underlying these measures is the creation of appropriate barriers so that infectious material borne or harboured by persons or vehicles in regular contact with a large-scale cattle unit does not gain access to the premises where the animals are kept. If such precautions fail, facilities should be available for prevention of the spread of infection. These would include arrangements for the reliable early diagnosis of infectious diseases and for the isolation of infected animals in each cattle production unit. The kind and nature of these arrangements may vary from one country to another, but infectious disease control should form an integral part of the management routine.

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Meeting physiological needs

Another important criterion for the safe operation of large-scale production systems is the manner in which the physiological needs of the animals are satisfied. For housed livestock, the stall and its equipment represent the immediate environment in which they spend the greater part of their lives; the relation of the animal to its environment can therefore be characterized as a state of interdependence, a changing but always intricate and intensive interrelationship which accounts for about two thirds of the variation in animal performance. It has been found that the environmental needs of animals become more sophisticated as their genetic potential for high production improves.

Cows kept in loose housing are accommodated either in single boxes or in groups. Single boxes are more expensive but are better able to satisfy the environmental needs of high-producing dairy cows. They facilitate longer hours of quiet rest by protecting the cows from

disturbance by group mates, and this results in improved production. But since bedding is usually not provided in single boxes, the disposal of liquid manure produced by the cows presents a problem which has still not been resolved, and which increases costs.

The agrocomplex system

The agrocomplex system of dairy cattle farming was developed in Hungary for the management of units of 520 or 1 040 cows under a loose housing system. Export demands for both variants of the system have been considerable. The dairy cows are kept in loose houses with lying boxes, and the feeding passage is installed either on both sides of the house or in the centre, with internal feeding stalls.

The standing or lying of the cows in the stalls is controlled by an adjustable metal railing mounted above the stalls, and excreta are discharged into the dung passage.

The average milk yield per lactation under this system is 6 000 litres for purebred Holstein-Friesian cattle, and 4 500 to 5 000 litres for Holstein-Friesian × Hungarian Fleckvieh crosses. Milk yields per hectare of fodder crops are expected to reach 7 000 litres, while one man-hour of labour input is required for every 75 to 100 litres of milk produced. One of the latest model milking plants is installed in the milking parlour.

The milking routine involves ushering a group of 100 cows into the collecting yard and then to the milking parlour by way of a fenced passage. Milking is always performed at the same time each day, not only for reasons of management routine, but also in the context of neurohormonal regulation of milk let-down. Care is also taken to avoid stress or irritation during milking. The cows react to frequent changes of dairymen and to the presence of visitors during milking by prolonging their milking time. Also, there is usually a significant decrease in yield (Table 1).

Loose housing with lying boxes. Single boxes are more expensive but are better able to satisfy the environmental needs of high-producing dairy cows

Group keeping on deep litter

The system of group keeping on deep litter is widely practised in many dairy units. It has been found that a strict social order becomes established in all groups of cattle maintained under this system, and the social rank usually depends on the body dimensions and ages of group mates. For this reason, grouping of dairy cows should preferably be based on performance characteristics, and exchange of animals between groups should be avoided if possible. A newcomer is bound to disturb the established hierarchy, and milk production is usually depressed in the whole group until a rearrangement of the social order is established. Competition for lying, feeding and drinking places increases with the rise in population density. Aggressive behaviour tends to become more pronounced when the group size increases. The optimal group size depends on various factors, including parity in milk production among group mates and the total amount of milk produced in the herd. In Hungary, group sizes of 40 to 50 have proved to be most advantageous, but good results have also been obtained with groups of 80 to 100 imported purebred Holstein-Friesian cattle.

Permanent individual marking of each cow is important in group keeping because it is indispensable for health control, mastitis prevention and identification of cows in oestrus.

Management factors

Technical facilities in large dairy units should conform to the habits and behavioural patterns of the cows. It is known, for example, that cows prefer to lie down for 12 to 14 hours of the 24 if a comfortable lying place is available; both flooring and bedding should therefore be suitable. If the lying place is uncomfortable, the cows are forced to stand for longer periods of time than is their habit (Table 2). Cold, moist or rigid floors and a lack of litter are predisposing conditions for mastitis. The incidence of mastitis has been shown to rise in stalls with inadequate flooring and low standards of hygiene. Thus, mastitis can be caused by many factors, and its effective control would require the elimination of various adverse environmental factors.

Mention should also be made of the different types of drinking devices, which may greatly influence both water intake and milk yield in cows. It has been demonstrated that bovines drink 30 to 40 percent more water from broad bowls or troughs than from valve-operated drinking devices. An unsatisfactory device may thus be responsible for low water intake and for the con-

Table 1 **Impact of disturbing factors on milking time and milk yield**

Type of milking unit	Group	Undisturbed milking process		Disturbed milking process	
		Average milking time	Average milk yield/cow	Average milking time	Average milk yield/cow
		min:sec	*litres*	*min:sec*	*litres*
Tandem milking parlour, 4 stalls	1	6:50	7.21	8:09	6.93
	2	7:14	6.37	9:21	5.94
	3	6:33	6.42	6:57	6.12
Tandem milking parlour, 8 stalls	1	7:30	5.62	9:11	5.52
	2	7:15	6.11	10:07	5.62
Herringbone milking parlour, 10 stalls	1	10:12	5.20	12:00	4.63
	2	10:15	4.90	11:15	4.02
Herringbone milking parlour, 16 stalls	1	9:30	3.95	9:42	4.00
	2	8:52	4.15	10:14	3.71

SOURCE Hauptmann, 1969

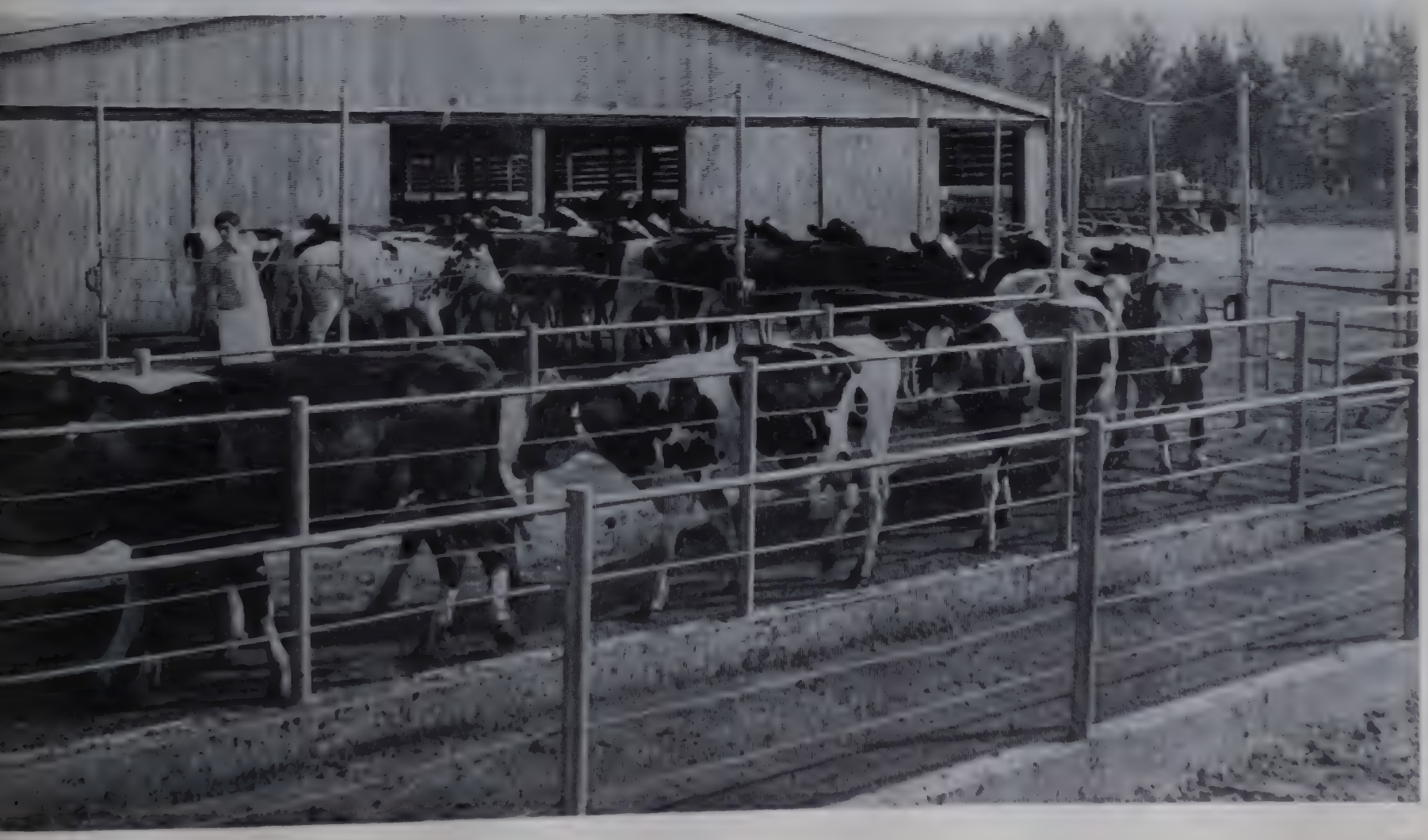
rnal lateral feeding passage of an agrocomplex cowhouse

s are driven through a fenced passage to the collecting yard of the milking parlour

sequent depression in milk production. It is therefore imperative that drinking bowls or troughs facilitate an intake of at least 6 litres of water per minute per animal.

A high reproduction rate with minimal rearing losses are important objectives in all large cattle production units. To minimize calf losses, it should be emphasized that life does not commence at birth, but at the time of fertilization of the ovum. Prevention of losses should therefore begin at the onset of gestation. Since the maternal organism represents the immediate environment of the developing embryo throughout its gestation, the specific and non-specific resistance of the newborn calf will greatly depend on the management and feeding of the cow during her period of pregnancy, especially in the third trimester. It is also known that antibodies to various infectious agents (bacteria and viruses) are transmitted to the newborn calf via the maternal colostrum. It is thus of fundamental importance that calving take place in the same unit in which the dam was kept during the second half-term of her pregnancy, so that the newborn calf will be protected by the maternal antibodies developed to all the pathogenic agents present in the unit.

Calf losses can be notably reduced in large units if special premises in which environmental germ contamination is low are reserved exclusively for calving and the housing of the calf during the early puerperal period. In herds free from infectious disease, and in fattening herds regularly put to pasture, the newborn calf is maintained with the dam in an isolated box for seven to ten days, after which dam and calf are turned out to graze together.



A practice that has recently been adopted in Hungary is to tie down in single stalls heifer calves intended for breeding, from birth to weaning (at 70 to 80 days of age), in order to prevent the spread of tuberculosis and viral diseases by contact. The calves are pail-fed, using two pails per calf, one for milk or water and the other for offering the starter feed. This system not only prevents the spread of infection, but also has the additional advantage of depressing the sucking stimulus: calves tied down from birth to weaning do not usually suck one another in the loose housing conditions to which they are exposed later, where this behavioural trait is obviously undesirable. At about three months of age these heifer calves are transferred to enclosed houses with an open yard. In the warmer zones these houses are built like barns. After reaching about 180 kg live weight the animals are then transferred to special heifer-rearing units.

The heifer house is open at one side and the animals are kept in groups on deep bedding. The use of slatted floors without bedding in such premises results in shortened lying periods and an increase in the incidence of foot diseases. Each heifer house has an open yard which the animals can use at leisure, but according to practical observations, more exercise is generally needed than is possible under such conditions. Turning out to pasture throughout the grazing season has therefore been greatly encouraged.

Table 2 **Lying times of cows tied down in stalls with different types of flooring**

Type of bedding and flooring	Percentage of 24 hours	Lying time in minutes	Percentage in relation to lying time on 4 kg straw bedding
10 kg straw litter, concrete floor	49.0	702	+2
4 kg straw litter, concrete floor	48.1	687	—
1 kg straw litter, concrete floor	[1] 45.6	649	−6
Perlite litter, concrete floor	[1] 45.1	645	−6
Wood shavings, concrete floor	[2] 42.8	611	−11
Sawdust, concrete floor	[2] 42.2	607	−12
Wooden slatted flooring	[3] 35.3	509	−26

SOURCE: Czakó, 1974.

[1] Scarcely noticeable decrease in milk yield. — [2] 3 to 5 percent decrease in milk yield. — [3] 10 to 15 percent decrease in milk yield.

From the collecting yard, cows will enter the milking parlour

Table 3 **Influence of drinking device on water intake of cows, at daily production level of 12-15 kg milk**

Type of drinking water supply	Average daily intake	Frequency of drinking in 24 hours	Water intake per minute
	litres		*litres*
Valve-operated automatic device	26.2	79	4.22
Pail drinking every other hour on 8 occasions	33.2	41	5.38
Ad lib. supply in drinking bowls not valve-operated	35.9	108	5.52

SOURCE: Czakó, 1974.

Use of pasture

Putting heifers out to pasture has various advantages besides feed economy. Pasture provides an ideal environment in which the animals not only thrive, but also reinforce their powers of resistance. Grazing also satisfies many of the physiological needs of the bovine, thereby promoting metabolic activity and the development of a strong and healthy constitution.

Appropriate use of pasture, with alternation of the grazing area, is important for the reduction of losses from parasitic diseases. It is known that pasture infestation increases parallel with the number of parasite-infected grazing animals and with the degree of infestation of the hosts. Irrigation of the pasture with sewage or liquid manure often results in massive contamination with salmonella species, which are a great health hazard, particularly to young calves. It is therefore imperative that rest periods for pasture be strictly observed.

Drainage ditches are another serious health hazard. They are sources of leptospira, liver fluke, lungworm, enteric parasites, etc., which could give rise to epidemic-like outbreaks in the herd if the animals drink from them regularly and graze alongside them. Antiparasitic treatment of the herd is therefore essential before spring grazing begins. Care should also be taken to prevent excessive multiplication of parasites in the grazing areas.

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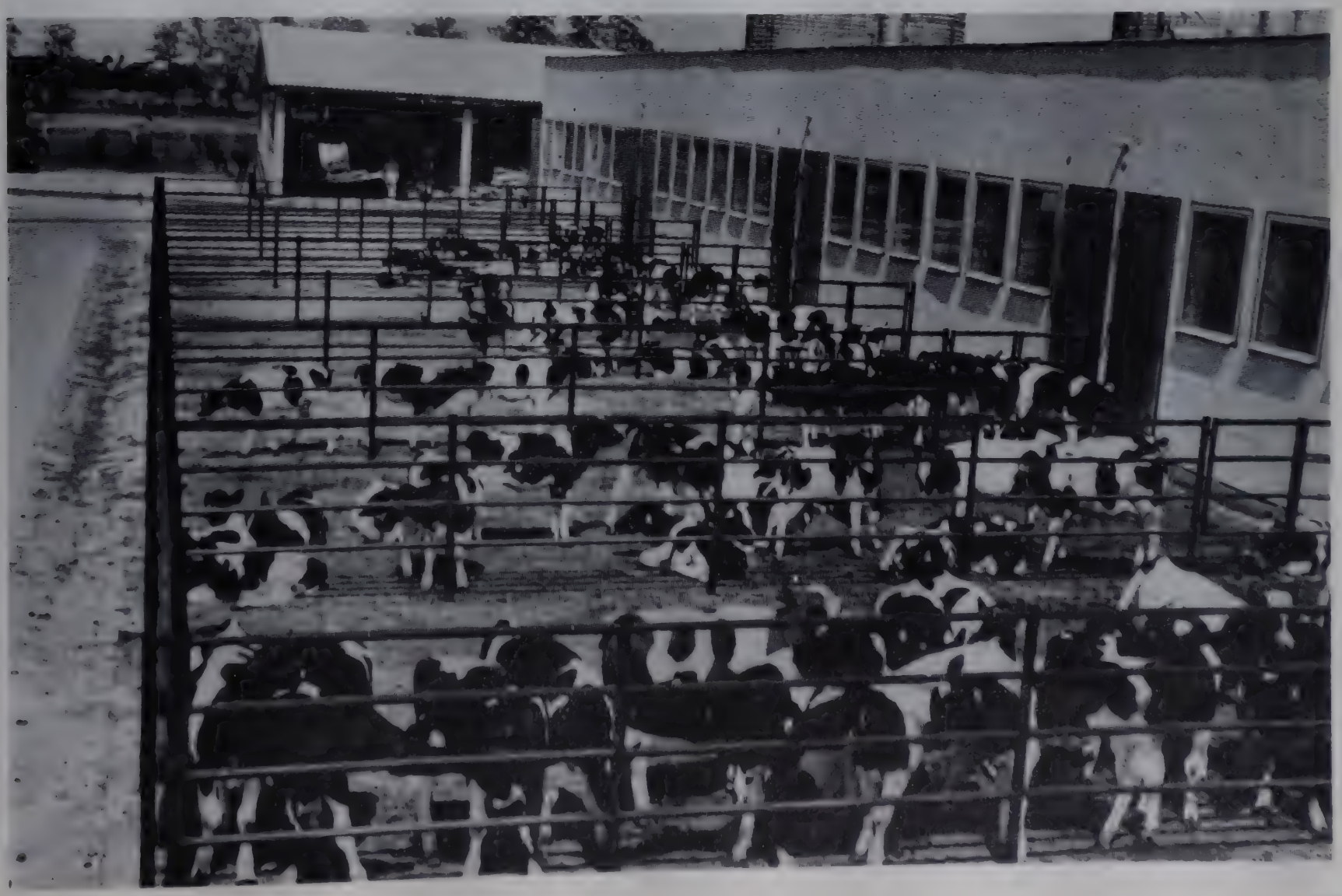
Enclosed house with open yard for growing heifers at the Alag State Farm in Hungary



managerial shift

by A. H. Somjee and Geeta Somjee

Women have long had most of the responsibility of running the dairy economy of rural India. They look after the milch animals, milk them, and carry the milk to collection centres run by private traders or dairy cooperatives. However, they have been given little credit for their contribution to dairy development and have not been accorded institutional positions commensurate to their manifold responsibilities. This has been true of all developing countries; since in every sector of the economy women have always remained in the background, it has often been taken for granted that in dairying, too, their role is insignificant.

This article will attempt to demonstrate that this attitude is gradually changing. Their role as the principal managers of the dairy economy is being recognized by dairy organizers, administrators, economic planners and politicians, and more extension work aimed at increasing milk production and improving animal health and management is being directed toward them. It has been found that when rural women are exposed to the various facets of modern dairying, in particular to concepts of organization and technology, they become more receptive to new ideas. This, in turn, has facilitated the launching of new programmes for economic development.

The influence of the Kaira Union

The key moving force behind dairy development in India has long been the Kaira District Cooperative Milk Producers' Union Ltd, located in Anand, western India. It has not only brought prosperity to the region where it is located, but has also succeeded in stimulating the growth of similar dairy cooperatives in other parts of the country.

About a decade ago, Kaira Union organizers realized that women played a key role in the development of milk production and that their perception of the various coordinates of dairying influenced production levels. Since women were involved in so many activities related to milk production, the dairy organizers decided to orient their demonstrations toward the women themselves rather than let them pick up information second-hand from their men. Trained technicians accordingly directed a good part of their extension activities to women, particularly in relation to the health, well-being and maintenance of cattle and buffaloes.

The organizers also emphasized the need for rural women to understand the technique and programme of artificial insemination which had been initiated with cattle and buffaloes in 1950. This led to a more widespread adoption of artificial breeding programmes to facilitate greater genetic improvement and regular breeding, and also influenced considerably the practices of feeding and management of the pregnant cow.

The cooperative's reward structure, also directed to women, was a further recognition of their role in dairy development. Rewards were made to women from each village on the basis of the milk produced by their cows; those with the highest yielding cows were presented with shiny stainless steel milk vessels as a token of their contribution to the progress of dairying.

The cooperative played a significant role in involving women in the running of dairy cooperative societies in their respective villages. This proved to be particularly successful in the rural communities in western India where, relatively speaking, women are more involved in decision-making than in the rest of the country. This may be partly attributed to the long tradition of public participation developed by women during the struggle for Indian independence and their subsequent continued association with political and social welfare activities. Consequently, it was not uncommon to find men and women working side by side in various voluntary undertakings of a traditional or non-traditional nature. In a number of villages women were active members of their local councils, and in some cases they held positions of responsibility in these bodies.

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Indian women acquire a new role in dairying

A dairy cooperative member talks with a Kaira Union adviser. In India, women have long undertaken most of the tasks related to keeping milch animals and marketing milk. Dairy cooperatives are now according them credit for their contribution to the dairy economy by directing more extension work toward them. As a result, women now face men with more self-confidence

The Khadgodhara example

An outstanding example of these developments is provided by the rural community of Khadgodhara in western India, where women established and are managing a dairy cooperative. So far-reaching was the cooperative's stimulus to social change that women were able to acquire formal recognition for themselves as the principal managers of the dairy economy. All the executive committee members and the shareholders of the dairy cooperative were women, and they managed and controlled all its activities. Khadgodhara was neither typical nor indicative of a new trend. What it did portray was a situation wherein social change and its implications were assimilated by the community well enough to allow women to undertake the entire organization of the village dairy cooperative.

Khadgodhara is situated about 80 km from the Kaira Union's headquarters in Anand. Access is difficult because of poor roads. Unlike most other villages in the area, it did not have electricity. It was long regarded as a haven for outlaws, and district administrators considered it a punishment station. Yet within a decade, the economic and social life of the village has changed radically, and one of the factors responsible for this was the establishment of a dairy cooperative.

An unusual combination of circumstances led to the village having its own dairy cooperative run entirely by women. The greatest obstacle to earlier efforts to form a dairy cooperative in Khadgodhara was the existence of another dairy cooperative in a village about 2 km away. At that time, the women of Khadgodhara walked to the neighbouring village twice a day to make milk deliveries. They showed little enthusiasm for this, and during the monsoon season they often put their surplus milk to extravagant domestic use. Apart from the physical effort involved in making milk deliveries, the milk producers of Khadgodhara found that they were ineligible for their share in the annual bonus because they could not become members of the dairy cooperative in the neighbouring village.

While this unsatisfactory state of affairs continued, certain political changes began to take place inside Khadgodhara under the leadership of a Brahmin widow. She was first elected to the village council as a member, and in 1967 became its chairman. In 1968 she attended a high-level seminar organized by the Kaira Union on how cooperative dairying could raise the standard of living of the rural poor. The seminar gave her the much needed opportunity to make a further attempt at forming a dairy cooperative in her own village. Although there was reluctance to support a new dairy cooperative in close proximity to an already existing one, she was able to persuade the Kaira Union that the Khadgodhara women would be able to run the cooperative with their own resources. On this basis, the Khadgodhara dairy cooperative was initiated with the enthusiastic support of the other women in the village. What began as a gimmick — women looking after public institutions — soon caught on. The women who ran the organization became deeply involved in what they were doing, and through the dairy cooperative they found institutional expression and formal recognition for an activity in which they had been engaged for a long time.

Such a managerial shift in the dairy economy of the village would not have been possible but for the leadership provided and the gradual assimilation of the norms of social equality by the community as a whole.

A cooperative member milks the family buffalo. Most families have only one animal, but some have decided to become real dairy farmers, and are slowly building up small herds

And there was another reason why such a managerial shift became possible. The village had a large population of Venkars (ex-untouchables) and Muslims, and the bulk of the milk producers in the village came from these two communities. The neighbouring village, despite directives from the Kaira Union, had in the past consistently discouraged Venkar women from delivering milk to its cooperative. The husbands of the Muslim women, with their traditional protective attitude toward women, disliked sending their wives to another village twice a day. Consequently, the Venkar and Muslim women did not require much persuasion to join the new dairy cooperative. The Brahmin lady in fact succeeded in enrolling at least one woman member per household in the cooperative — a feat which surprised even the Kaira Union organizers. Today all the shareholders and organizers are women.

The entry of women into various institutional positions as shareholders and members of the executive committee had a far-reaching effect on their perception of themselves. They now face men with more self-confidence than before. They are also relatively less inhibited when it comes to dealing with men from outside their own village.

The women of Khadgodhara are aware of the fact that they have made inroads into areas traditionally reserved for men. In the past the women looked after the cattle, milked them, and carried milk for sale whenever necessary. They knew that in neighbouring villages the institutional positions, even those relating to the dairy economy, were occupied by men. Now that the women controlled one of the organizations in their own village, they felt that they had to give a good account of their ability, and therefore sought to display a level of efficiency that would earn the respect of the men of the village, the district, and the Anand Milk Union Ltd. (AMUL) dairy plant.

A dairy cooperative member feeds her buffalo as her daughter looks on. Income from milk has always been regarded as pin money earned by the women of the house, who look after the animals, milk them and sell the milk

The women involved in the running of the dairy cooperative set aside their personal ambitions; their primary goal was to give a good account of themselves collectively. Consequently, their obsession with success often shielded them from any potential divisiveness.

No conflict situation arose between the men and the women of the village because of the women's involvement in organization activities. Since the women had organized the dairy cooperative from the beginning, the men neither questioned their efficiency nor begrudged their formal positions. As the organization was run entirely by women, it did not arouse the jealousy of the men. However, an organization with a mixed composition might have been the target of male suspicion and interference.

Nothing is too good for the family buffalo; this one is washed down as she eats. Milk is considered as a source of extra income, and a good level of production has enabled many a poor family to save money and invest in animals or land

The plight of widows

The poor and the very poor of rural India are seasonally employed agricultural labourers, and among them are persons who have no wage-earning relatives. They constitute about 15 to 20 percent of the rural population, and include a number of widows. While male seasonally employed agricultural labourers may be able to find work at some distance from their villages during lean periods, such an undertaking is not possible for middle-aged and often old and ailing widows. During such long spells of unemployment, the destitute widows are often helped by their neighbours in return for assistance in domestic jobs.

Whenever village dairy cooperative societies announce the resumption of loan facilities for purchasing buffaloes, the village widows make full use of such opportunities. Indeed, their escape from poverty and destitution lies in the availability of such loans. But the average cooperative is usually unable to activate its loan mechanism because of continuing default by some of its members. In some villages, the needy families and destitute widows had to wait as long as six years before they could persuade the dairy cooperatives to make loans available to them.

The impact of dairy cooperatives

The dairy cooperatives often stimulated the efforts of rural families to increase their production of milk and trade the resulting surplus for cash. In such efforts, women, with their propensity to save, often played a vital role. This was particularly true of women from the poorer strata of society. While the rich farmers often used up most of their surplus milk to make *ghee* (clarified butter) for domestic consumption, the poor, under the watchful eye of their women, sold as much milk to the cooperative as was possible. This in fact happened in many of the villages acting as feeders to the AMUL dairy. The farmers from the poorer strata of village society sold much more milk, and with the help of their sales proceeds bought more buffaloes or land, or used it to repair their dwellings, purchase ornaments, or meet wedding expenses.

The income from milk was regarded as an extra income which was not meant for subsistence as such, despite heavy pressures experienced by the average village family for subsistence spending. It was often considered a means of enhancing one's economic security. So strong was the desire to save, despite the lack of adequate capacity in most cases, that in certain villages the dairy cooperatives were requested to make weekly rather than daily payments for the milk.

The income from milk was regarded as pin money earned by the women of the house. Since the women were in charge of the various responsibilities relating to the feeding and management of the animals, and since they also marketed the milk to the village cooperative, they were the recipients of the sales proceeds. Therefore, the men usually conceded the claim of the women to the money that they earned from the sale of milk and let them decide how it should be utilized.

The village dairy cooperative thus became a symbol of what could be achieved by technology, organization, and institutions that are geared to the widest possible social benefit. The range of activities undertaken by the cooperative had a great impact on the outlook of the women directly involved in it. The cooperative eliminated the middleman's profit, and gave members a fair return for their produce. It helped to improve their year-round economy and contributed significantly to the provision of better feed for the animals, improved health care and higher yielding cows. The average farmer was thus able to achieve a higher economic standard, and above all became more receptive to new ideas. Thus, when new breeds of cattle were brought to the area.

there was little resistance — particularly on the part of the women — to accepting them as new and potential sources of increased milk production.

Wherever a dairy cooperative was established, the farmers' perception of their own health care changed rapidly. The range of activity connected with animal health care, as undertaken by the cooperatives, provided them with new norms, and the farmers and their wives became increasingly critical of existing standards of human health care. They came to feel that human beings were not as well looked after as their milch animals.

Of particular interest was the exposure of women to the programme of artificial insemination of cattle and buffaloes. Its underlying implications did not go unnoticed. What became evident to them was the fact that the size and quality of the family were a matter for human manipulation rather than something over which one had no control. Nevertheless, further research still remains to be done in the field of women's perception of family planning, especially in villages where an AI programme has been in existence for some time.

Conclusion

This article has attempted to demonstrate that modern dairying has effectively related itself to the women of rural India by helping to break through the barriers of their seclusion and change the status that traditional society has accorded them. The involvement of women in the various facets of planning for increased milk production and improved collection and marketing practices has brought them out of their limited world of domestic chores and childbearing into the mainstream of social life. Through such developments, the dairy industry has opened up new vistas for economic growth in which women — a hitherto untapped resource for economic development — can play a leading role.

Village women watch intently as a Kaira Union veterinarian vaccinates a buffalo against rinderpest. The cooperative maintains a veterinary service for the livestock of members. This initiative has not only instilled in the women an awareness of the need to keep their animals healthy, but also an interest in improving standards of human health care

Recycling of swine waste by aerobic fermentation

by B.G. Harmon

In recent years, research has indicated that swine waste can be put to several uses. While fertilizer might still prove to be the most effective of these uses, there are now possible alternative choices. One such alternative involves the recycling of excreta by aerobic fermentation. Feeding programmes based on biologically enhanced swine waste have currently advanced from hypotheses based on chemical analyses to accepted practice on some pig farms.

The recycling of swine waste for pig feeding has not received as much research attention as the feeding of poultry waste (Fontenot and Webb, 1974; Smith, 1974) and cattle waste (Anthony, 1974) to ruminants. This is undoubtedly due to these animals' different capacities for utilizing nitrogen, a valuable component of the wastes of all species. Ruminants can effectively utilize non-protein nitrogen including urea and uric acid, but pigs must have preformed amino acids in their diets.

Nutritional value of swine waste

Typical pig diets based on maize or sorghum and including adequate protein supplements are about 85 percent digestible; the remaining 15 percent consists principally of fibre, ash and indigestible protein. Diggs *et al.* (1965) demonstrated that swine waste scraped from a concrete feeding floor and dried could be used to substitute 15 percent of a typical pig diet without depressing performance. But when substituted for 30 percent of the diet, feed efficiency decreased, although Parker *et al.* (1959) had found that the phosphorus in waste is highly available. Orr *et al.* (1973) reported that freshly collected faeces do not support normal performance when substituted for 22 percent of a complete diet. However, research at Michigan State University (Orr *et al.*, 1973) and at the University of Illinois (Harmon *et al.*, 1972) has been based on a biological upgrading of the total animal excreta. This work has demonstrated that animal waste is of greater nutritional value after bacterial fermentation. It involved the collection and processing of the waste in an oxidation ditch beneath slatted floors (Day *et al.*, 1969) with the waste serving as a substrate for the production of single-cell protein. Evidence of the efficacy of this bioenhancement is provided in Table 1, which shows the increase in concentration of the different amino acids. Non-protein nitrogen is converted into single-cell protein, while poorly digested proteins such as hog hair and sloughed cellular debris are hydrolyzed and fibre is digested.

When Holmes *et al.* (1971) screened the contents of an oxidation ditch, they found that the percentage of dry matter and the protein in the dry matter increased as the size openings in the sieves decreased (Holmes *et al.*, 1971). Analyses of the various fractions (Harmon, 1972) showed that the amino acid content increased significantly as particle size decreased (Table 2). The fractions containing microbial cells had the greatest concentration of protein and amino acids.

Oxidation ditch mixed liquor

A typical nutrient analysis of oxidation ditch mixed liquor (ODML) based on weekly samples is shown in Table 3 (Harmon, 1972). In addition to amino acids, ODML is rich in calcium and phosphorus (more than 3 percent of each) as well as in the trace elements normally added to pig diets. But although the dry matter is rich in nutrients, it constitutes only 4.5 percent or less of the total material. Drying or concentrating ODML creates problems in handling, preserving and cost that appear to be prohibitive. In early studies, the material was collected for feeding by slowly draining the

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A pig drinking water from an ODML trough

oxidation ditch and recovering the solids from the bottom. It was found that this product containing 27 percent protein could be substituted for half of the protein supplement in a maize-based diet for rats and could maintain liveweight gain and efficiency equal to the control diet (Harmon *et al.*, 1972). But as it was the only protein supplement for maize, it failed to support normal growth. Chastain *et al.* (1975) have reported similar results with dried products from aerated swine wastes.

However, it was subsequently determined that the fluids drained away in the process of recovering the solids were rich in amino acids. Sieving and centrifugation also proved to be inefficient procedures because the smallest particles that are the last to be removed are the richest in amino acids. In view of the difficulty of resolving this problem economically, it was decided to feed ODML as a nutrient solution in all subsequent trials. The procedure that was evolved has practical application in that the pig normally consumes two parts of water per part of dry feed. In addition, liquid effluent has been a source of pollution on some pig farms.

Feeding trials

A marginally deficient 12 percent protein diet containing 0.5 percent lysine was fed to two groups of pigs. Those consuming the diet mixed with ODML were able to correct for amino acid deficiencies, and their protein intake thus increased by 2 percent and lysine by 0.1 percent. They gained weight significantly faster and more efficiently that those offered the diet mixed with tap water through the 50 to 100 kg weight range (Harmon *et al.*, 1973).

An alternate feeding method was later devised to simplify the feeding procedure. The same 12 percent protein diet was offered *ad libitum* in self feeders and ODML was provided from the oxidation ditch by constant or intermittent pumping through a trough in each pen. Control pigs received water from a tap. Pigs offered ODML gained more rapidly and efficiently through the 40 to 100 kg weight range (Table 4) than those given tap water (Harmon and Day, 1974).

Miller *et al.* (1974) have also provided oxidation ditch liquor to finishing pigs through troughs in a similar manner. But in their trials, pigs fed this nutrient solution gained more slowly and less efficiently than those provided tap water. However, in these studies ammonia nitrogen constituted 33 to 41 percent of the total nitrogen, and it would appear that with this amount of ammonia

there would have been insufficient oxygen to sustain an aerobic environment. Nevertheless, in a more recent study Miller and Miller (1975) have reported a better performance from pigs fed the oxidation ditch liquor.

Earlier studies of Harmon *et al.* (1973) are relevant in this connexion. They reported that performance was reduced when products of an anaerobically maintained ditch were fed. In studies with pigs and rats, any substitution of anaerobic products for maize or soybean meal resulted in reduced gain and efficiency. The lower performance was not a function of reduced feed intake. Other evidence (Harmon, 1975) also demonstrated problems with inadequate aeration. By operating the oxidation ditch at less than full speed, dissolved oxygen was detectable only part of the way round the ditch as evidenced by the odour and colour of the material. Thus the ditch did not remain aerobic and finishing pigs fed with ODML gained more slowly and less efficiently than pigs offered tap water with their dry diet.

An overaerated oxidation ditch also creates problems in that nitrates can increase the liquids to a toxic level. Overaeration may result from an excess input of oxygen or an insufficient addition of substrate (swine excreta). A normal range for use in recycling studies reported by Harmon and Day (1974) is 70 to 225 ppm nitrate in the ditches.

The microorganisms present in the oxidation ditch are primarily those that grow selectively on Chapman Agar medium, namely staphylococci (Table 5). Most pathogenic organisms do not compete effectively in an oxidation ditch; salmonella organisms have never been isolated.

However, roundworm (*Ascaris lumbricoides*) eggs are sustained in an oxidation ditch. When a ditch becomes contaminated with these eggs, they will be consumed by the pigs and present problems. One trial with ODML was discontinued after one week because the oxidation ditch was found to have a high concentration of worm eggs. An oxidation ditch can be cleared of eggs by allowing it to become anaerobic for one week and then restarting the aeration; the eggs are microbially digested in the process. The best procedure, however, is to avoid the introduction of eggs.

At the conclusion of every experiment in which ODML was fed, pigs have been slaughtered for inspection

Table 1 **Amino acid composition of swine faeces**

	Fresh swine faeces [1]	Dried swine faeces [2]	Oxidation ditch mixed liquor [3]	Oxidation ditch liquor [2]
Phenyalanine	0.81	0.87	1.48	1.66
Lysine	0.60	1.11	1.42	1.60
Arginine	0.44	0.67	1.28	1.45
Threonine	0.53	0.80	1.96	1.22
Methionine	—	0.58	0.77	0.60
Isoleucine	0.52	1.03	1.49	1.54
Leucine	0.92	1.57	2.79	2.13

[1] Gouwens, 1966. — [2] Orr *et al.*, 1973. — [3] Harmon *et al.*, 1972.

Table 2 **Analyses of various sieved particles of ODML**

Screen [1]	Size opening (inches)	Protein	Lysine	Histidine	Threonine	Methionine	Isoleucine
		Percentage of dry matter					
20 mesh	.0328	8.4	0.38	0.24	0.98	0.32	0.81
50 mesh	.0117	11.1	0.92	0.52	1.57	0.42	1.13
100 mesh	.0058	20.0	1.36	0.98	2.01	0.62	1.66
200 mesh	.0029	75.6	3.08	1.32	2.44	1.27	2.20

SOURCE: Harmon, 1972

[1] Material passing through screen, remaining in solution.

of lymphatic and liver tissues; no differences were observed due to treatment.

Other advantages

Another advantage of recycling swine waste is that it helps to reduce or eliminate liquid, solid or gaseous effluent from pig houses. In the oxidation ditch, the water is partly evaporated and partly consumed by the pigs. When ODML was fed in our system, it was necessary to add 9 litres of water per pig per day to the oxidation ditch in the summer and 6 litres in the winter to maintain a constant operating volume (Harmon and Day, 1975). The likelihood of pollution becoming a problem and the need for an area for waste disposal were thus found to be minimal. The refeeding of biologically enhanced swine waste therefore allows the producer not only to increase the utilization of the nutrients in the animals' diet, but also to reduce the environmental pollution hazards associated with livestock feeding.

Table 3 **Amino acid and mineral content in dry matter of swine ODML**

Amino acid [1]	%
Phenylalanine	1.48
Lysine	1.42
Histidine	0.47
Arginine	1.28
Threonine	1.96
Valine	2.06
Methionine	0.77
Isoleucine	1.49
Leucine	2.79
Aspartic	3.73
Serine	2.55
Glutamic	5.06
Proline	1.29
Glycine	2.29
Alanine	2.83
Tyrosine	1.17
Tryptophane	0.28
Mineral [2]	**%**
Calcium	3.33
Phosphorus	3.83
Magnesium	1.49
Sodium	2.75
Potassium	4.04
Iron	0.5507
Copper	0.0071
Zinc	0.1148

SOURCE: Harmon, 1972.
[1] Means of 13 weekly analyses except for tryptophane, for which one analysis was made. — [2] Means of six weekly analyses.

Table 4 **Daily weight gains and feed/gain ratios in pigs offered tap water or ODML as the source of water**

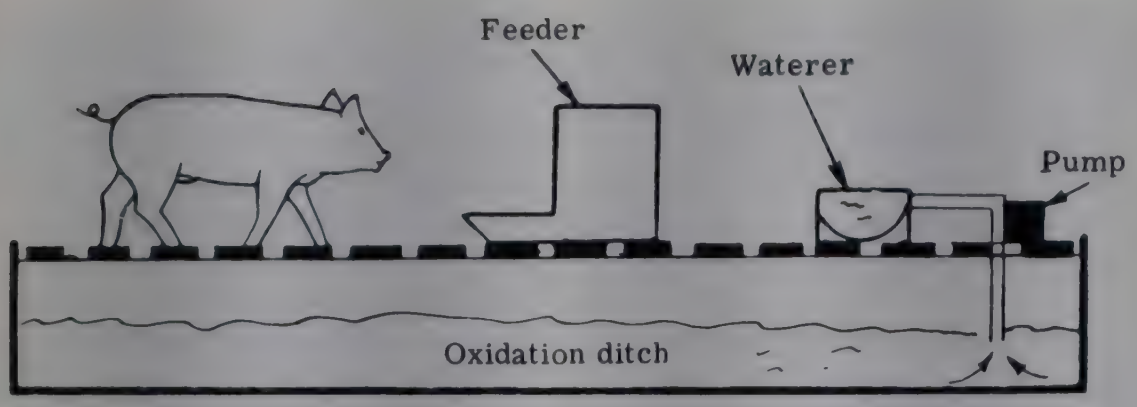
Rep.	Daily gain, kg [1]		Feed/gain [1]	
	Tap water	ODML	Tap water	ODML
1	0.61	0.63	3.33	3.25
2	0.66	0.70	3.38	3.37
3	0.77	0.90	4.10	2.92
4	0.60	0.72	4.35	3.60
5	0.58	0.66	3.85	3.80
6	0.71	0.79	3.24	2.96
Mean	[2] 0.66	[2] 0.73	[2] 3.70	[2] 3.32

SOURCE: Harmon and Day, 1974.
[1] Each value represents 10 pigs. — [2] Significantly ($P < .05$) different.

Table 5 **Microbial population in oxidation ditch mixed liquor**

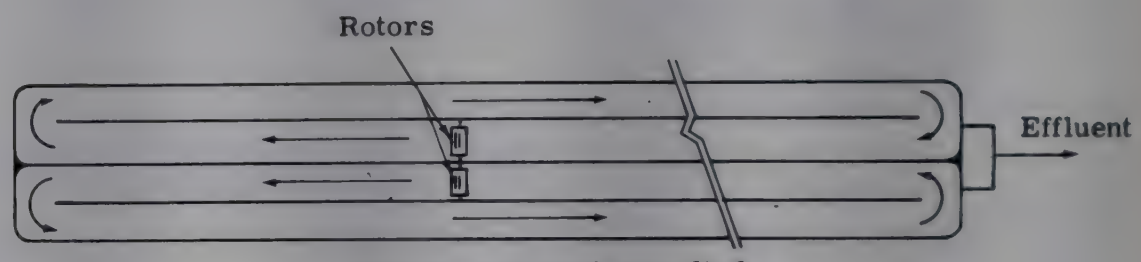
Media	Predominant organism	Counts [1]		
		1 000/ml	SD	%
Tryp-agar	General	2 015	28.2	100
KF Strep	Grp D streptococci	102	1.4	5.1
Staph 110	Staphylococci	1 510	91.9	74.9
Malt (pH 3.5)	Mould	69	2.8	3.4
MacConckey	Coliforms	60	2.8	3.0
Tomato juice agar	Lactobacilli	81	4.2	4.0

SOURCE: D.J. Grunloh in personal communication.
[1] Three observations on each media (weekly samples).

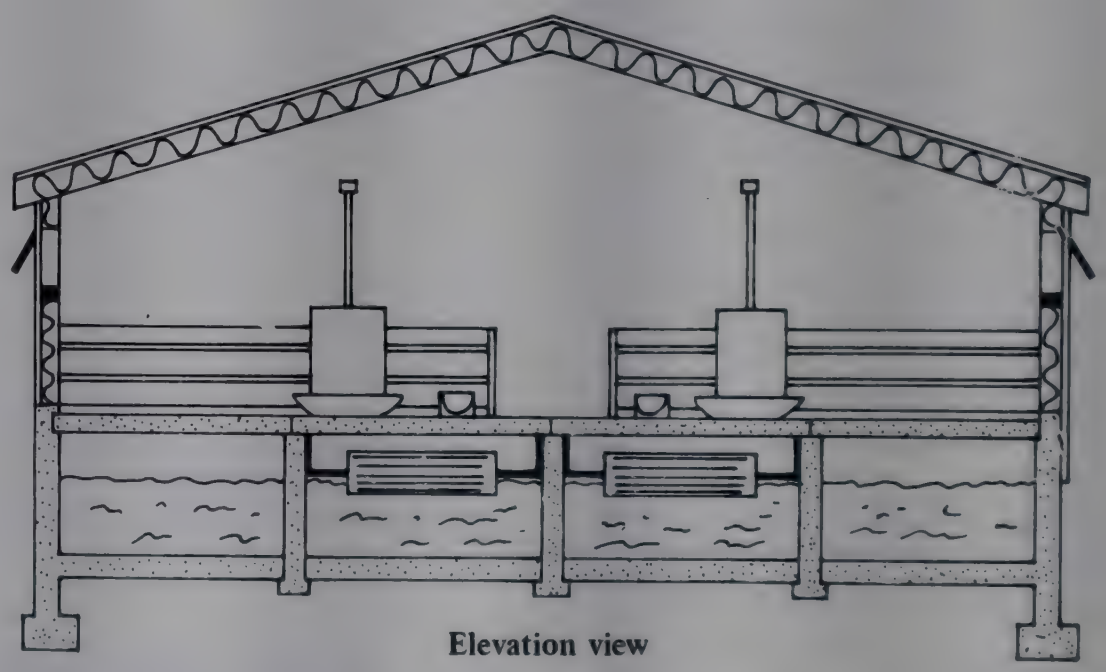


(Left) FIGURE 1. Totally slatted swine confinement building with an oxidation ditch beneath the self-cleaning slatted floors

(Below) FIGURE 2. Schematic view of feeding system. ODML is pumped from the oxidation ditch directly into a watering trough. No other water is provided



Plan view of oxidation ditch



Elevation view

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Production of single-cell protein for animal feed from lignocellulose wastes

by W. Dexter Bellamy

Waste recycling has been advanced as a method for preventing environmental decay and increasing food supplies. The potential benefits from a successful recycling of agricultural wastes are enormous. It may be the only method for large-scale protein production that does not require a concomitant increase in energy consumption. In addition, it may be the most effective method for producing animal and human food from lignocellulose materials that are now of little nutritive value and are therefore used as fuel.

This article discusses the present status of microbial protein (single-cell protein) production from agricultural wastes and describes some of the technical and economic problems that must be overcome before large-scale application is possible.

Background

The volume of the various wastes available for production of single-cell protein (SCP) annually in the United States is presented in Table 1. While most other countries are not as profligate as the United States, the worldwide volume of lignocellulose wastes must exceed the volume of agricultural products used directly for human consumption. It is evident that the conversion of photosynthetically produced organic compounds into human and animal food is the limiting process in human food production. The worldwide annual production of organic material by photosynthesis has been estimated to be between 25 and 50 tons per caput. Any practical method capable of converting a small fraction of this yield into human food should find wide application and go a long way in reducing chronic food shortages.

The growth of microorganisms, more rapid than that of the higher plants, makes them very attractive as high-protein crops; while only one or two grain crops can be grown per year, a crop of yeasts or moulds may be harvested weekly and bacteria may be harvested daily. The use of microorganisms as a source of protein for human and animal food is not a new development. Traditional foods and feeds such as cheese, sauerkraut, miso and silage have a high content of microorganisms to which their nutritional properties are due in part. The high-quality proteins synthesized during the growth of these microorganisms compare favourably with those derived from the better grains. There are many references to the amino acid composition and the protein quality of SCP (Shacklady, 1975). While there is little data on animal feeding trials using SCP produced from lignocellulose wastes, there is a large and growing body of information about SCP from petroleum. This information should be applicable to SCP from agricultural wastes with proper allowance for the undesirable contaminants in the sources. In petroleum there has been concern for accumulation of carcinogenic hydrocarbons. In agricultural wastes, there is concern for accumulation of pesticides and herbicides. The International Union of Pure and Applied Science has published a report (IUPAC, 1974) on guidelines for testing of SCP as a major supplement in animal diets and should be consulted for further details on feeding trials. Many more feeding trials will be needed before

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SCP from lignocellulose wastes is accepted for routine feeding.

Rapidly growing organisms such as bacteria and yeasts contain a higher uric acid content than slower growing plants and animals. While the uric acid limits the daily intake of SCP for humans and monogastric animals such as pigs and chickens, ruminants such as cattle, sheep and goats can tolerate higher levels. There are several methods available for removal of uric acids (Sinskey and Tannenbaum, 1975).

Production methods

Some of the proposed methods for conversion of agricultural wastes into animal feed are presented in Table 2. These methods will be briefly evaluated in the following. First, a distinction should be made between the production of SCP from the lignocellulose parts of the plant and the production of SCP from the soluble carbohydrates of many agricultural wastes. Several processes for utilization of waste solubles have been proposed (Sloneker *et al.*, 1973; Anthony, 1971), and some are now being tested. The Ceres Ecology Corporation of Chino, California in the United States will process waste

Table 1 **Solid wastes in the United States**

Waste type	*10^9 tons per year*
Agricultural and food wastes	400
Manure	200
Urban refuse	150
Logging and other wood wastes	60
Industrial wastes	45
Municipal sewage solids	15
Miscellaneous organic wastes	70
Total	940

SOURCE: Humphrey, 1975.

from over 100 000 dairy cattle for feed recycling and for control of salt in ground water. Other plants in Toulouse, France, Zacantecos, Mexico, and Sterling, Colorado in the United States use processes that depend upon an anaerobic fermentation in a silo or covered ditch. The manure undergoes a lactic acid fermentation due to the action of anaerobic bacteria (chiefly streptococci and lactobacilli), and a typical silage odour results in place of the odour of manure. These short-time anaerobic fermentation processes do not utilize the fibre, and are therefore a partial solution to the waste problem. The fibrous residue may be used as a soil conditioner before or after composting. It appears that under special conditions, the fermented solubles can be substituted for 8 to 10 percent of the high-protein component of the feed with a saving of 10 to 20 percent in total feed costs. There appears to be no major technical obstacle to commercial development of this type of waste recycling, although the pesticide accumulation question has not been completely settled.

Technical problems

The more important and difficult problem of waste fibre utilization requires microorganisms that can utilize lignocellulose. Unfortunately at present there are no known microorganisms that will utilize natural lignocellulose at rates of commercial interest. It is necessary, therefore, to pretreat the wastes. The purpose of the pretreatment is twofold: to expose the cellulose by removal or modification of the lignin, and to reduce the crystalline fraction of the cellulose. Several methods of pretreatment have been proposed, including wet and dry ball milling, wet

Table 2 **Methods for conversion of cellulosic agricultural wastes into animal feed**

Treatment	Microorganism	Substrate	Protein produced	Fibre utilized	Reference
Ensiling	Mixed anaerobes	Wastelage	Slight	No	Anthony 1971
Dilute alkali	None	Straw	No	Yes	Rexen 1975
Aerobic mesophiles 25°C	Cellulomonas	Bagasse	Yes	Yes	Dunlap 1975
Mould growth 25°C	Trichoderma viride	Waste paper	Yes	Yes	Mandels 1974
Aerobic thermophiles 55°C	Thermoactinomyces	Fermented livestock wastes	Yes	Yes	Bellamy 1975

and dry grinding, hot alkali and anhydrous ammonia. Both ball milling to micron-size particles and hot alkali (0.5 N H Cl 120°C for 15 minutes) are effective pretreatment methods for releasing most of the cellulose. Up to 90 percent of the cellulose is made available for microbial digestion. Alkali treatment based on recent modifications of the Beckman process has been proposed as a direct method for converting straw, maize cobs, etc., into a more digestible feed (Rexen, 1975). This method does not increase the protein content of the feed because there is no microbial growth. It does, however, increase the availability of cellulose to the rumen bacteria. It can be considered a pretreatment method for SCP production by the rumen microorganisms. The method consumes relatively large amounts of alkali and its economic value is still under investigation.

Rates of soluble sugar utilization of 10 to 30 grams per litre per hour have been reported for SCP production by yeast. Rates of 5 to 15 grams per litre per hour have been claimed for utilization of selected hydrocarbons. In order for SCP to be an economic process under present market conditions, the rate of utilization of cellulose must be at least 1 to 5 grams per litre per hour. As no pilot plants have been operated, it is not possible to report commercial rates, but laboratory scale fermentors have been run at 1 gram per litre per hour on pretreated wastes. The studies reported by the Louisiana State University group (Dunlap, 1975) were on a gram negative aerobic bacteria, *Cellulomonas* sp., which grows rapidly on cellulose at 25 to 30°C, but cannot utilize lignin or lignocellulose. Therefore extensive pretreatment with hot alkali is required. The small (one micron) organism must be harvested by centrifugation. Amino acid analysis and small animal feeding trials have shown that a high-quality SCP is produced.

The group at Natick, Massachusetts (Mandels *et al.*, 1974), has reported on the use of enzymes produced by the mould *Trichoderma viride* for production of soluble sugars from waste paper cellulose. These sugars can then be fermented by yeasts or bacteria for SCP production. As now envisioned, it is a four-step process:

1. Pretreatment of waste by ball milling or hot alkali.

2. Enzyme production by growth of *T. viride* on pretreated cellulose.

3. Depolymerization of cellulose by *T. viride* enzymes.

4. SCP production by yeast or bacteria. Although mutated strains of *T. viride* with several-fold increase in enzyme production have been obtained, this process appears too complex to find wide application for agricultural use.

As indicated in Table 2, we have worked with thermophilic aerobic microorganisms (growth temperature 55°C). There are several advantages to the use of aerobic thermophiles:

(*a*) The product is pasteurized after a growth period of 10 to 24 hours, i.e. after all bacteria, virus and parasites pathogenic to humans and animals have been killed.

(*b*) The growth rates are faster.

(*c*) Fermentation temperature using ground water is more easily controlled.

(*d*) Aerobic microorganisms may utilize lignin and lignocellulose while anaerobes cannot.

Thermophilic microorganisms were collected from a wide variety of sources including local compost heaps and manure piles, lumber mill waste piles, salt water and fresh water mangrove swamps, the anomalous hot earth areas of Yellowstone National Park, and a tropical forest. After screening many organisms, the thermophilic actinomyces were selected as the most promising of the microorganisms growing on cellulose and lignocellulose. These organisms exhibit optimum growth at a temperature of 55°C and a pH of 7.5 to 7.8. They produce extracellular cellulases with a pH optimum of 6.0 and a temperature optimum of 65 to 70°C. A demonstration plant was built at Casa Grande, Arizona in the United States to produce enough SCP for animal feeding trials and to find answers to many questions that could not be answered by laboratory experiments. The engineering experiences of this plant were reported by Nolan and Shull (1973). Unfortunately, for a variety of technical reasons including culture instability, heavy metal contamination and product variability, SCP production was discontinued and the animal feeding trials were not completed. At that time, the U.S. Food and Drug Administration had not issued clear and complete guidelines for necessary feeding trials of recycled animal feed, and therefore the size, duration and cost of the trials could not be determined. The demonstration plant has not been reopened because of economic reasons.

Economic problems

In the long term, any process must generate enough profit above operating costs to attract investment capital. Production of SCP from lignocellulose wastes is no exception to this general rule. SCP must be

produced at a price that is competitive with the major conventional protein sources of plant and animal origin. If there is a guaranteed payment for waste removal, the production costs will be reduced accordingly. But no credit can be taken for waste removal in the absence of a firm and long-term commitment. At mid-1975, SCP was unable to compete with soybean meal (US$112 to 140 per ton). The SCP from petroleum development is in a similar economic bind. Because of the increase in the cost of petroleum and the fluctuating prices of soybean meal and fish meal protein, the start-up of large-scale plants in Europe has been postponed for several years, despite heavy investment in large modern production facilities (Skinner, 1975).

Some factors that will contribute to reducing costs of SCP production from agricultural wastes are the following:

(*a*) Payment for waste disposed (negative cost of raw material).

(*b*) More effective and less expensive pretreatment.

(*c*) Superior microorganisms with a more rapid growth rate.

(*d*) Superior microorganisms that can rapidly utilize natural lignocellulose without pretreatment.

(*e*) Methods of SCP production that do not require stirred tank fermentors.

(*f*) Methods of SCP production from high solids-low water fermentations.

(*g*) Methods that will decrease the capital investment.

It is obvious that the value placed on waste elimination is variable and will depend upon the laws and customs in each region. Local laws providing credit for waste disposal are an effective method for stimulating SCP production.

There is very little work in progress on a low-technology, labour-intensive, low-capital SCP system. It is an area with great potential for the developing countries, but of lesser interest to the industrialized countries or to the private sector of industrial countries because it does not appear to be a large potential market for sophisticated equipment and processes. It is in this area of controlled fermentation under non-sterile conditions with a minimum of equipment that methods may be developed for using agricultural wastes at the small farm level (Imrie, 1975). Instead of being grown under sterile conditions in expensive stirred fermentors, the moulds are grown in a plastic container under conditions where the desired organisms predominate.

Conclusions

An industry for the production of SCP from lignocellulose wastes based upon capital-intensive, high-technology, low-labour processes will not develop for several years because of technical problems and economic considerations. The technical problems can be overcome and will be solved when the economic climate improves.

The potential for a labour-intensive, low-technology, low-capital industry in the less developed countries will not be realized unless research in this area is greatly expanded.

Private sector capital from the developed countries cannot be expected to invest in the latter type of development because it will not provide a large market for sophisticated equipment and processes.

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ANIMAL FEEDS AND MEAT: CURRENT SITUATION AND PROSPECTS *

ANIMAL FEEDS

Coarse grains

The world grain supply situation has eased further because the U.S.S.R. shortfall in production will not be entirely made up by imports, and because of the excellent rice crop in Asia. For the first time since 1972, coarse grain supplies in the major exporting countries are large enough to meet effective demand and allow a marginal increase in carryover stocks in these countries. Global import requirements of coarse grains are now estimated at 67 million tons for the 1975/76 season. However, there is still uncertainty as to the amounts of grain that will be fed to livestock during the current crop year. If a substantial economic recovery gets under way in the industrial countries, this should increase demand for animal products and thus for feed grains, since present grain/livestock price relationships favour the feeding of grains. Reflecting the improved supply/demand situation, world market prices have remained relatively stable since the end of last year. Reports of planting intentions and growing conditions for the 1976 coarse grain crop are still too incomplete for even a preliminary estimate for the world as a whole. However, production prospects for crops for spring harvesting in the southern hemisphere are less favourable than last year in all the larger producing countries except Brazil.

Oil cakes and meals

The outlook for world production of oilmeal protein in 1976 is that output from current crops will reach the record level of 33.1 million tons protein equivalent. This would be sharply higher than in the previous year, and about 1 million tons above the figure suggested by the extrapolation of the long-term trend. In addition, exporters' opening stocks were probably not less than 2 million tons. Despite price ratios between grains and protein feeds that favour the increased use of oilmeal, demand (which for most of 1975 was depressed by the widespread economic recession and unprofitable feeding margins) began to pick up in the last quarter. Demand in the main consuming countries is expected to continue recovering during 1976 (aided by a likely continuation of relatively low prices for protein and of the favourable grains/oilmeal price ratio), but the strength of demand both in developed market economies and in the U.S.S.R. remains uncertain. Even under optimistic demand forecasts, stocks of oilseed protein (mostly in the form of soybeans) are expected to increase considerably during the season.

World supplies of *soybeans* are expected to be at record levels. In the United States the crop is now estimated at 41.4 million tons (25 percent up from the relatively small crop of the previous year, and only slightly less than the record crop of 1973). Since beginning stocks are also larger than last year, total United States supplies (at 46.4 million tons) should be at a record level. Brazil's 1976 crop, now being harvested, is widely expected to reach 11.5 million tons, a 20 percent rise from the record 9.6 million ton crop of 1975. Output of *groundnuts* is also expected to show a sharp recovery, mainly due to a record forecast crop in India and somewhat larger output in some African countries. Higher *rapeseed* output is expected, particularly in Canada. In contrast, world *cottonseed* output will decline as a result of the sharp reduction in areas planted in the United States and many other countries. *Sunflowerseed* production is expected to fall for the second consecutive year, due to the low yields and small crop in the U.S.S.R., the major producer. The outlook for *fish meal* production in 1976 is very uncertain, particularly in view of the scarcity of suitable fish off Peru in the latter part of 1975 and continuing doubts as to when full fishing will be resumed.

MEAT PRODUCTS

Cattle inventories at the beginning of 1976 were lower than at the same period in 1975 in most major northern hemisphere importing countries, marking the end of the latest cyclical expansions. The reductions in the United States and the European Economic Community were due to heavy slaughterings (especially cows and heifers) and smaller live cattle imports in 1975, while slaughterings accounted for the decline in Japan. Continued herd build-up has been reported from practically all southern hemisphere exporting countries. A cyclical increase is expected in pig numbers in North America and Europe. Owing to shortages of feedgrains, livestock slaughterings in the U.S.S.R. were substantially above 1974 levels, especially in the autumn months. Mainly pigs and poultry were affected, as cattle numbers were officially reported to be rising. At the beginning of 1976 pig numbers on state and collective farms were down about 22 percent while cattle numbers were up 3.5 percent. The decline in pig numbers on other holdings was about 11 percent smaller.

In recent months changes in feed and livestock prices have continued to indicate that livestock feeding in western Europe and North America is gradually regaining profitability. Should this trend persist, larger fed-cattle and slaughter pig and poultry supplies can be expected in the second half of the year. There are, however, many uncertainties in regard to grain prices, pasture conditions and fodder supplies in the months ahead, as well as the extent of the expected economic recovery which will determine consumer demand for meat. While 1976 beef production is likely to be significantly lower than in 1975 in western Europe and Japan, it is expected to show a small increase in North America. Shortfalls in beef production will be at least partly compensated by increased production of poultry meat and, to a lesser extent, pigmeat. The decline in U.S.S.R. pig inventories will have a marked impact on meat production. Better grain harvests could result in another expansion of poultry meat output in the second half of 1976, but this would not offset the decline in pigmeat production. Domestic meat supplies could also be influenced by a recently reported shortage of forage availabilities which might cause an increase in cattle slaughterings and beef production.

* As of 20 February 1976.

World beef trade is likely to show a modest recovery in 1976, as imports are forecast at higher than the depressed 1975 volume in most importing countries. Prices have also improved somewhat, and this could continue for the rest of the year, particularly if the rise in pigmeat supplies remains moderate and economic recovery gathers strength in the importing countries. An important factor will be the eventual purchases of the U.S.S.R., which has been a large importer of meat in the past two years. The size of these purchases is likely to depend — as in the past — on the price at which meat will be available on the world market later in 1976.

Export availlabilities are expected to rise further in the main southern hemisphere exporting countries. The largest increases against 1975 are forecast in the Latin American exporting countries. Trade in feeder cattle could also increase in North America if profit margins can be maintained in feeding operations. In western Europe, the major change in this trade was the almost complete shift in Italian cattle and calf purchases from third countries to EEC suppliers during the last two years. Unofficial estimates indicate an increase from about 1.4 to 1.5 million head in the first three quarters of 1975 compared with the same period of 1974. The share of third countries in this total fell from 34 to 4 percent during the 1974-75 period.

Control of Newcastle disease

At the Fifth World Congress of the World Veterinary Poultry Association held in Munich in 1973, Walker and Omohundro (1973) drew attention to the need for cooperation among countries if outbreaks of virulent Newcastle disease are to be prevented or lessened. The need for exchange of information was also considered necessary.

Lancaster (1975a) has reviewed the comments presented by Walker and Omohundro and suggested that from the point of view of disease control, a situation has been reached whereby it is often impossible to move poultry genetic material to and from certain areas of the world.

Related to the prevention of disease is the problem associated with the numbers of poultry involved. Thus, Robertson (1967) has stated that "it is not generally realized that many of the classical formulae of population genetics are only valid if the population size is of the order of thousands."

For many years, Newcastle disease has been of considerable importance in world trade and the economics of the poultry industry (Cockrill, 1971). Thus, the eradication or control of the virulent or velogenic form of this disease is of considerable importance to many, if not all, countries. Experiences in Canada have confirmed reports from other countries (Lancaster and Alexander, 1975) that outbreaks of velogenic Newcastle disease can be reduced or eradicated by classical disease control procedures (Lancaster, 1975b).

The first case of viscerotropic velogenic Newcastle disease (VVND) to occur in Canada was diagnosed in July 1971, and from that date until the last outbreak in July 1973, five distinct outbreaks occurred in poultry flocks. The origins of these outbreaks were not determined with certainty. However, likely means of spread between premises involved in an outbreak were determined in some instances. No further incidence of the disease has been reported in domestic poultry since December 1975.

The general world incidence of velogenic Newcastle disease requires that very strict import controls be maintained by Canada. Commercial importations of all avian species and hatching eggs from countries other than the United States are controlled by import permit. Before a permit is issued, consideration is given to the species of birds involved, the country of origin and the suitability of the quarantine premises in Canada.

Velogenic strains of Newcastle disease virus have been isolated from some shipments of cage and pet birds, especially psittacine birds, while under quarantine in Canada. However, there has been no evidence of spread of the virus to domestic poultry flocks.

In Canada, a federal slaughter policy under the Animal Contagious Diseases Act is enforced as soon as the disease is reported. Premises are placed under quarantine and a diagnosis is made as quickly as possible. All domestic poultry within a five-mile radius are placed under surveillance. Slaughter of the infected flocks and disposal of all carcasses are conducted with minimum delay.

Each outbreak of VVND in Canada has been eradicated. For the individual farmer, an outbreak of the disease causes financial loss. Although the owner is compensated at market value for poultry ordered slaughtered and eggs destroyed, there is an overall loss from the cost of cleaning and disinfection and the general disruption of business. Nevertheless, the eradication of VVND has been aided by the response of the poultry industry to the need for prompt reporting of suspected outbreaks. This has permitted prompt diagnosis and slaughter of infected flocks. Experience indicates that for an eradication programme to be successful, it must be accepted by the poultry industry. This aspect is of considerable importance and has been emphasized by Hutchinson (1975) in Northern Ireland.

In Canada, as an added precaution, vaccination using live lentogenic vaccines only is conducted on a voluntary basis. However, it is recognized that at the present time a large percentage of the national flock is susceptible to virulent Newcastle disease.

From 1966 onward, a number of countries in several geographical regions (16 countries during the 1966-72 period) have reported a decrease in incidence of velogenic Newcastle disease (Lancaster and Alexander, 1975). Although this number of countries is small, the combined experience might nevertheless support the thesis that under certain conditions the velogenic form of Newcastle disease can be controlled and eradicated.

However, it must be recognized that the conditions favourable for the control and eradication of velogenic Newcastle disease have not yet been defined in sufficient detail. The world incidence of virulent Newcastle disease will decline only when the conditions involving the virus, the host and the environment are better understood.

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Hides and skins industry beset by problems

Excessive price fluctuations in the world market, the very wide variety of raw hides and skins, and growing competition from cheaper plastic products are the major problems confronting the hides and skins industry today. The FAO Committee on Commodity Problems has also highlighted the dearth of sound information on hides and skins as a further obstacle to the development of the industry. An intergovernmental meeting has therefore been called to improve the collection of data, to deal with general economic and trade problems, and to examine the possibility of establishing a permanent intergovernmental body on hides and skins.

International trade in hides, skins and leather goods (excluding furs) now amounts to about $4 000 million per year. The importance of the industry to the developing countries is illustrated by the fact that in India hides and skins have reached third place in exports in terms of value.

Hybridization between bison and cattle

Worldwide publicity and extravagant claims continue to be made concerning the outstanding performance of the "beefalo." Historically, the name buffalo derives from "beef" and "buffalo," which is the American name for the bison — *Bison bison*. In international agricultural terminology the word "buffalo" refers to the Indian water buffalo, *Bubalus bubalis*, which is quite a different animal. The water buffalo will not hybridize with cattle.

At the end of the 19th century, several breeders in the United States and Canada realized the advantages of producing an animal that would combine the size and hardiness of the bison with the growth rate and carcass quality of beef cattle. They proceeded to make the cross of bison males with Hereford or Angus dams. Male calves from this cross were rare; few of them survived and none was fertile. The name "cattalo" was coined 70 years ago for these cattle × bison hydrids, and there is no good reason to give up that name.

Although the cattalo had the expected advantages of disease resistance, survival in snow, large size, efficient growth and good carcass development, these early attempts to fix a new type seem to have been discontinued, presumably because of the fertility problem. The primary defect in cattalo semen is the absence or low concentration of spermatozoa; primary spermatocytes are formed, but reduction division does not take place.

Recent publicity material on bison × cattle hybrids has been widely circulated under the name beefalo by the firms that are marketing these animals from east of the Mississippi in the United States, and by their agents. According to these reports, the beefalo was developed after 15 years of work by Mr. D.C. Basolo, a rancher of Tracy, California. The first cross was a bison bull on to a Charolais cow and the final beefalo is 3/8 bison, 3/8 Charolais, 1/4 Hereford. It is claimed that a beefalo can reach a market weight of 1 000 lb (454 kg) at 12 to 14 months (8 to 9 months in some reports) when fed solely on roughage (grass or silage). They are also said to produce one pound (0.45 kg) of lean meat from every 4.5 pounds (2.21 kg) of roughage that they consume. Other claims are that the meat contains 19 to 22 percent protein and about 7 percent fat, that it is "short grain, succulent and has a very delicious flavour" and that the beefalo has a resistance to many common diseases of cattle and can easily adapt to most climatic conditions.

If these claims are correct, the biggest breakthrough is clearly the high fertility of the cross. But neither Mr. Basolo nor the firms and agents marketing the animals have revealed how the problem of male sterility in the hybrid can be overcome. The claims in regard to growth and feed conversion efficiency have also not been substantiated by controlled comparisons of the beefalo with the bison and with the Charolais and Hereford breeds from which it is said to have been derived. Equally, the claim that it should be possible "to breed a buffalo that would be resistant to the tsetse fly" is too fantastic to be believed unless the promotors of the beefalo provide a reasonable basis for their statements.

I.L. Mason

First International Symposium on Feed Composition, Animal Nutrient Requirements and Formulation of Rations for Livestock

This symposium sponsored by the International Network of Feed Information Centres (INFIC), the Committee on Animal Nutrition of the National Research Council (National Academy of Sciences), the United States Agency for International Development (USAID) and the International Feedstuffs Institute of Utah State University will be held in Logan, Utah from 11 to 16 July 1976.

The theme of the symposium is using feed composition data and nutrient requirements information in the formulation of rations for livestock. Mathematical models that describe the utlization of nutrients by animals will be emphasized. The aim is to use feed information and equations that describe nutrient utilization and animal requirements to produce the most profitable diet formulae for animals in various physiological states and environments. Methods of solving livestock feeding and management problems will be presented.

The working language of the symposium will be English. However, interpreters will be available for French, German, Portuguese and Spanish. The major topics to be discussed are feed composition, nutrient utilization, calculation of animals' requirements, formulating diets for maximum profit, and practical systems of diet formulation and animal management. One session will be devoted to formulating diets with tropical feeds. There will also be a practical diet formulation workshop.

Further information may be obtained from:

Dr. Lorin E. Harris, Director, International Feedstuffs Institute, Animal Science Department, Utah State University, Logan, Utah 84321, United States

European Association for Animal Production

The 27th annual meeting of the European Association for Animal Production will be held in Zurich, Switzerland, from 22 to 28 August 1976. The study commissions on animal genetics, animal nutrition, management and health, cattle production, sheep and goat production, pig production and horse production will convene during this week and conduct both individual and joint sessions. Among the subjects to be discussed are: methods of sire evaluation for dairy bulls, new research results in animal nutrition, reproduction control and efficiency in dairy and beef cattle, the report of the working group on breed comparisons, reproductive efficiency of prolific breeds of sheep, feeding by-products to sheep and goats, economic efficiency of pig breeding schemes, and evaluation of productivity tests in horses.

Further information may be obtained from:

Schweizerische Vereinigung für Tierzucht
c/o Herrn H. Glattli
CH-3303 Jegenstorf
Bantigerweg 42
Switzerland.

Tropical animal production

This new journal is being published jointly by the Consejo Estatal del Azúcar, Dominican Republic, and the Banco de Crédito Rural del Golfo and the State Government of Quintana Roo, Mexico. It appears in both English and Spanish editions, and aims to provide a forum for research papers in tropical animal production. The promise is also made to reduce publishing time to a minimum of three to four months by using offset reproduction direct from typescript. The first number of 1976 is dedicated to the proceedings of the recent meeting held in Santo Domingo, Dominican Republic, from 8 to 10 December 1975, on the use of sugarcane and its by-products for cattle feeding. Subsequent editions will contain research papers in the general field of ruminant production in the humid tropics. Original contributions in this field written either in Spanish or English are welcomed.

The price per volume of three numbers is US$10.—. Requests should specify either the English or Spanish edition.

Inquiries should be sent either to Centro Dominicano de Investigación Pecuaria con Caña de Azúcar, CEAGANA, km 10½ Carretera Mella, Santo Domingo, Dominican Republic, or to Centro de Investigación y Experimentación Ganadera, Alvaro Obregón No. 227, Chetumal QR, Mexico.

International Hill Land Symposium

An International Hill Land Symposium will be held at West Virginia University, Morgantown, West Virginia, United States, from 3 to 9 October 1976. The Symposium will be co-sponsored by the U.S. Department of Agriculture, the American Forage and Grassland Council, AID and other agencies, and will consider problems of the effective utilization of hill land and marginal land for agricultural production in developing and developed countries. Topics will include potential of hill land and economics of utilization; multiple use of hill land; problems of disturbed land areas; hill land improvement techniques; hill ecosystems; crop and animal production systems; and social and cultural factors.

For further information write to:

Dr. R.L. Reid

Hill Land Symposium Committee
College of Agriculture and Forestry
West Virginia University
Morgantown, West Virginia 26506
United States

NEW BOOKS

Newcastle disease virus and spread - a review of some of the literature

LANCASTER, JOHN E. and ALEXANDER, DENNIS J. Canada Department of Agriculture, Ottawa, Canada, 1975. Monograph No. 11. 79 pages, 20 figures, 15 tables, 2 epizootiological maps. (In English with English and French summaries)

The monograph is a revised edition, or perhaps more accurately, a supplement to the earlier monograph "Newcastle Disease — a review 1926-1964" by Lancaster. The new monograph reviews some of the literature published since 1964. It comprises two parts:

Part 1 deals with the morphology, structure, biochemistry, replication and classification of the virus. An extensive review has been made of strain variation in virulence, cytopathogenicity, growth and various biological activities, i.e. haemagglutinin, neuraminidase, haemolysin, haemadsorption and cell fusion. Attempts have been made to determine the biological activities which may be responsible for virulence and pathogenicity.

It is well known that virulent strains kill chick embryos more readily and produce larger plaques in chick fibroblast monolayers. Recent work shows that there was also a direct correlation between the virulence of the infecting strains and the amount of virus antigens present in homogenized infected chorioallantoic membrane, the degree of modification of the infected cell surface as measured by haemadsorption, and the rate of production of viral RNA. Furthermore, the accumulation of virus products may be responsible for the cytopathogenicity. This is the most up-to-date and comprehensive review of the nature of Newcastle disease virus available today, and it will be a useful addition to earlier reviews of its kind.

Part 2 concerns the spread of the disease since 1964 around the world and within a number of countries. This part should be regarded as a continuation to part 1 of the earlier monograph (Lancaster 1964) which reviewed the spread of the disease from 1926 to 1964. To understand the global spread of the disease, the present monograph should be read together with its predecessor.

Modes of spread of the disease from outside and within a country are discussed in detail with particular reference to experiencies in the United States, Canada and the United Kingdom. The importance of the role of wild or cage birds transported by air from South America and Asia in the introduction of the recent infection to North America and Europe is rightly emphasized. This is in contrast to the earlier slow spread of infection by movement of infected domestic poultry by sea or land. The other possible means by which the disease may be introduced and spread among domestic poultry and game birds are discussed in detail, i.e. the role of poultry markets and shows, hatcheries, poultry carcasses and offal, poultry vaccines and cell lines, transportation, backyard poultry, airborne dissemination on dust particles from intensive poultry houses, and human agency. Useful information is extracted from some recent experiences in the United States, the United Kingdom and Canada; obviously, the relative importance of the modes of spread varies from country to country.

An attempt is made to draw a global picture of the spread of the disease. Unfortunately, this is based on rather limited information from some of the published literature. Certain data presented in the two foldout epizootiological maps on the front and back covers are oversimplified. For instance, the route indicating the general spread of the disease in the Near East and then to Europe from 1966 to 1970 shows

spread from Iran in 1966 to the Persian Gulf in 1967, to Iraq in 1968, to the eastern Mediterranean in 1967 and 1968, to Egypt in 1968, to Greece in 1969, and to Hungary, the Federal Republic of Germany, the Netherlands, the United Kingdom and France in 1970. In actual fact, velogenic or peracute Newcastle disease had been endemic among backyard poultry in most of the Near East countries many years previously. The disease's development into a severe epidemic form in various countries coincided with the development of intensive poultry industries, especially broiler production, when large numbers of susceptible birds were exposed in an endemic area. This occurred first in Lebanon in 1958, in Egypt in 1965 and in Iran, Jordan, Iraq and Kuwait in 1966-67. As to the spread of the disease from the Near East to Europe, the only evidence given in the monograph is that of shipment of day-old chicks from Israel to Greece in 1969. No evidence is provided to support the suggestion that the disease spread from the Near East or Greece to Europe in 1970. On the other hand, there is strong evidence suggesting that the outbreaks in Europe in 1970 were caused by virus introduced from psittacine birds imported from South America.

Similarly, the foldout map on world distribution of Newcastle disease on the back cover is again oversimplified and far from accurate. It suggests that before 1968, virulent Newcastle disease was present only in South America, Southeast Asia, Africa and southern Europe. As a matter of fact, the disease was also widespread at least in Central America, the Near East, Japan, the Republic of Korea and China (Taiwan Province). Again, many more countries were known to be affected between 1927 and 1939 than those indicated on the map.

Despite these criticisms, the monograph will be a valuable reference on Newcastle disease, especially for those who have little access to some of the journals quoted. We are indebted to the authors for their tremendous effort in producing this useful monograph at a time when a global pool of information is needed to combat this urgent world poultry disease problem. Our gratitude also goes to the Canada Department of Agriculture for subsidizing the publication, thus making it available to workers all over the world.

H.P.C.

The science of providing milk for man

JOHN R. CAMPBELL and ROBERT T. MARSHALL. McGraw-Hill Book Company, New York, 1975. 801 pages, numerous figures, tables and references. Price: $47.50. (In English)

This book fulfils its promise to provide the reader with a fundamental understanding of dairy animals, dairy products, their manufacture and the scope of the dairy industry. It has been written primarily for use as a text by American college students taking courses in dairy and food sciences, but is also useful as a reference for teachers of vocational agriculture and for those organizations which provide services to the dairy industry. It relates principally to the United States dairy industry and the legislation governing it; this may limit its use outside that country. However, the basic principles and facts concerning the subjects presented are universally applicable. The text on each topic is brief and concise and well supported with photographs, tables, graphs, charts and illustrations, making the book enjoyable to read and easily digestible despite its length. Footnotes make useful references to sources where the reader can find more detailed information on the broad subjects dealt with.

J.M.

Animal Science - Reproduction, Climate, Meat, Wool

YEATES, N.T.M., EDEY, T.N. and HILL, M.K. Pergamon Press, Sydney, Oxford, New York, 1976. 389 pages. Price: $20, £8.35. (In English)

In 1965 Butterworths published a textbook by Professor Yeates entitled *Modern aspects of livestock production*. This was based on four courses of lectures given to senior students of agriculture in the Department of Livestock Production at the University of New England, Armidale, New South Wales, Australia. This book has now been brought up to date with the help of two of Dr. Yeates' colleagues — Dr. Edey for the section on reproduction and Dr. Hill for that on wool.

As this is not a general text on animal science, it is essential that the main title should not be used separately from the subtitle, which defines the book's scope. Furthermore, the animals covered are almost entirely restricted to beef cattle and sheep, although there are some references to pigs in the sections on reproduction and climate. Geographically, the emphasis is naturally on Australia, with South Africa also featured frequently. The section on wool deals chiefly with Merino wool. The beef breed regionalization scheme for northern Australia is discussed in detail.

Throughout the book, theory and practice are admirably blended — endocrine theory with practical use of hormones, reproductive physiology with treatment of infertility, meat histology with consumer preference, wool biology with the manufacturing process.

The photographs and diagrams are numerous and clear, and many have not been published elsewhere. There is a bibliography of about 900 references. In fact, the book is a little difficult to read in places because of the many citations, but it is a good reference book on the four subjects of the subtitle.

I.L.M.

Pigs and poultry in the South Pacific

IAN WATT and FRANK MICHELL. Sorrett Publishing Pty Limited, P.O. Box 94, Malvern, Victoria 3144, Australia, 1975. 93 pages, with photographs, diagrams and tables. (In English)

This book sets out, in simple language, the information required by extension workers and others responsible for helping farmers in the South Pacific with the production of pigs and poultry. It deals with all levels, from simple improvisation at the village level to semi-intensive and intensive types of production. Fifty-three pages are devoted to pig production and 22 to poultry production. It is not written as a textbook for developed countries, but workers from these countries, intending to help the less developed nations, might study this book carefully.

The authors have put together their experiences as extension officers in Papua New Guinea, and have succeeded in producing a useful and practical booklet.

D.K.

Proceedings of Seminar on Mastitis Control 1975

International Dairy Federation, place Vergote 41, 1040 Bruxelles. Edited by F.H. Dodd, T.K. Griffin and R.G. Kingwill. 510 pages. Price: 500 Belgian francs. (In English)

This seminar was organized by the National Institute for Research in Dairying, England, and the United Kingdom Dairy Association, under the auspices of the International Dairy Federation. The seminar was held at Reading University and was attended by 150 delegates from 24 countries. Its aim was to bring together people with a direct interest in the control of bovine mastitis. The proceedings include 63 papers which were presented at an introductory session and the following seven sessions: 1) diagnosis of mastitis and intramammary infection; 2) somatic cell counting; 3) prevention of infection; 4) elimination of infection; 5) special aspects of mastitis control and mastitis control systems; 6) implementation of control techniques; 7) conclusion of seminar.

The aim of the introductory session was to review briefly the whole field of mastitis problems, drawing particular attention to those aspects related to control methods. In the first session, the importance of standardizing sampling and diagnostic methods was stressed and working procedures were suggested. In the second session, electronic somatic cell counting was accepted as the best current practical method for use in milk quality and in mastitis control schemes. The third session focused on selected methods of preventing mastitis, e.g. hygienic measures, chemical disinfectants, conditions of milking with machines or by hand, and environmental stress. The fourth session covered various methods of eliminating intramammary infections by antibiotic therapy or by culling cows from herds. In the fifth session, the control of mastitis due to infections with relatively uncommon microorganisms was discussed and the need for specific experiments to examine the importance of coagulase negative micrococci and *Corynebacterium bovis* in mastitis control was recognized. The sixth session covered the economics of mastitis control and the role of veterinary surgeons and farmers in control systems.

The proceedings are of importance for people with a direct interest in the control of bovine mastitis who work in research, in the organization of control schemes, in extension services, or in the dairy industry.

Y.O.

Patterns of animal disease

Brendan Halpin. Ballière Tindall, 7 & 8 Henrietta Street, London, 1975. 184 pages, 35 illustrations. Price: £2.50. (In English)

This book deals with all aspects of epidemiology (epizootiology) of animal diseases. It covers the general principles of epidemiological study but not the details of particular diseases. However, a certain number of diseases have been referred to as examples of the characteristic features of some groups of animal diseases.

The book consists of nine chapters with several references at the end of each. The following subjects are covered: various modes of the continuity of infectious diseases in nature; the methods of epidemiological studies, such as case history studies, sampling methods, methods of collecting and handling data and methods of field survey; the validity, accuracy, specificity and efficiency of epidemiological tests; various routes and modes of dissemination of animal diseases; the role of reservoirs, carriers, vectors and the enemies of vectors in epidemiology; intrinsic factors such as age, sex and breed of animals which have connexions with the susceptibility and resistance of animals to diseases; relationship of certain extrinsic factors such as nutrition, housing and management to animal diseases; active and passive immunity and vaccinations; the epidemiology of non-infectious diseases and of less common conditions; international and large-scale epidemiological studies.

Since epidemiology covers such a wide range of subjects related to disease incidence, the exact role of epidemiologists in disease control is often questioned. In this book, the author attempts to answer most of the questions related to epidemiological studies of animal diseases. As pointed out in the introduction, we are all epidemiologists to some extent because epizootiologists are not only interested in the cause of disease but also in all the factors influencing that cause. Therefore, this book is useful not only for students and graduates of veterinary medicine and agriculture, but for all others who are concerned with the maintenance of animals in a state of good health and efficient production. It will also be of use to biologists in illustrating some aspects of the complicated interplay between disease and the environment and between the actions of man and the ecology of his animals.

Y.O.

Chianina cattle in the tropics

Bovino Chianina no trópico. J. Barisson Villares. (Extract from thesis presented to Faculdade de Ciencias Médicas e Biológica de Botuctu, Estado de São Paulo, Brasil.) 1975. Copyright by Associacão Brasileira de Criadores de Chianina. 203 pages. (In Portuguese)

Chianina cattle were first introduced into Brazil in 1956, and between 1964 and 1972 no less than 343 breeding animals were imported from Italy. This monograph describes the performance of some of these animals and their descendants during the period 1967-72 on four farms in São Paulo and two in Bahia. The experimental material covered 2 237 animals, including 70 Chianina, 35 Guzerá (Kankrej zebu), 552 Nellore (ongole zebu), 781 Tabapuã (polled zebu) and 799 Chianina × zebu F_1 crosses. Many aspects of response to environment, reproduction, growth and carcass quality were studied.

The main conclusions are as follows. The Chianina showed a remarkable tolerance to heat (e.g., it was prepared to graze in full sun) and a good reproductive performance both as purebred and as crossbred. The F_1 crossbreds responded well to tropical grazing and increased in weight at the rate of 0.25 kg of chilled carcass per day up to a slaughter age of 30-33 months. Dressing percentage averaged 55 and meat/bone ratio 4.7:1.

In addition to 100 tables there are numerous figures and photographs, many of the latter in colour. There is a review of literature, a bibliography of 240 references and a short summary in English, Italian, German and Spanish. Since this book is sponsored by the Brazilian Association of Chianina Breeders it is possible that it may present a rosy view of the breed. Nevertheless, it is clearly a valuable source of information, and even the non-Portuguese reader can pick out from the tables the figures which bear out the author's conclusions.

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